CONODONT DATA IN RELATION TO SEQUENCES ABOUT THE PRAGIAN–EMSIAN BOUNDARY (EARLY DEVONIAN) IN SOUTH-EASTERN AUSTRALIA

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Conodont data are presented for the Cavan Formation at Wee Jasper in south-eastern New South Wales, and from stratigraphic sections and numerous spot samples and partial sequences through the Buchan Caves Limestone in its major outcrop tracts in eastern Victoria. Data from these areas and from Devonian sequences at Boulder Flat and Tabberabbera, Victoria, enable approximate alignments to be made with respect to the Pragian–Emsian boundary using as criterion the first appearance of *Polygnathus dehiscens* (overlapping with *P. pireneae*).

At Wee Jasper, the boundary is inferred to occur approximately 35 m below the "Cavan Bluff Limestone". Near-ubiquity of Ozarkodinan Biofacies (with absence or near-absence of polygnathids) hinders precise correlation of horizons within the Buchan Caves Limestone, but a scatter of records of *P. dehiscens* indicates that, except at Bindi, at least the upper half of the Buchan Caves Limestone, and perhaps substantially more, is early Emsian. Dearth or absence of conodonts from the dolomitic lower portion of the Buchan Caves Limestone in its various outcrop tracts leads to uncertainty regarding precise alignment of this widespread transgression. The Heath's Quarry carbonate buildup at South Buchan is argued to have continued upward growth long after the transgressive event reflected in the spreading of the pelagic Taravale facies over the Buchan Caves Limestone in the Buchan–Murrindal–The Basin area. At Bindi, following this last transgressive event, carbonate sedimentation continued; the Buchan Caves Limestone there ascends from the *dehiscens* Zone into the *perbonus* Zone. Samples from Boulder Flat and Tabberabbera indicate the presence of the latest Pragian *pireneae–trilinearis* interval, the productive samples at Tabberabbera including clasts in the basal unit, the Wild Horse Formation.

"Spathognathodus" trilinearis Cooper is assigned to *Polygnathus* and a new species, *Ozarkodina pseudomiae*, is described.

LIMESTONES of Early Devonian age are widespread in south-eastern Australia. Some are autochthonous, such as the Buchan, Wentworth and Murrumbidgee groups of the Buchan–Bindi, Tabberabbera and Taemas–Wee Jasper areas of south-eastern New South Wales and eastern Victoria (Fig. 1). Other limestone bodies such as those at Loyola, Deep Creek (east of Walhalla), Coopers Creek, Marble Creek (old Toongabbie marble quarries) and the Tyers–Boola areas of east-central Victoria are allochthonous (including isolated megaclasts) or interpretable as submarine fan deposits (Conaghan et al. 1976; Mawson, Talent et al. in prep.; J. A. Webb pers. comm.). Some of these were the focus of pioneering investigations on conodonts 20–25 years ago (Philip 1965, 1966; Philip & Jackson 1967; Philip & Pedder 1967a; Pedder et al. 1970; Cooper 1973) on the basis of which substantial changes in long-accepted stratigraphic alignments were profferred (e.g. Philip & Pedder 1964, 1967b, 1967c; Pedder 1967). Since then there have been major advances globally in understanding the sequence of conodont faunas through the Early Devonian and, with this improved knowledge, has come greater precision in making stratigraphic alignments.

A renewal of investigations into the Devonian conodont faunas of eastern Australia has so far focussed on sequences not including late Pragian or earliest Emsian horizons (Pickett 1978, 1980, 1984; Mawson 1986, 1987a, 1987b; Mawson & Talent 1989; Mawson et al. 1985, 1988). This was an interval during which major transgressive and regressive (T/R) events took place. Syntheses of stratigraphic data relative to Devonian T/R events have been presented (Talent 1969, 1989; Talent & Yolkin 1987). General accounts of Australian Devonian conodont biofacies have also been presented (Mawson et al.

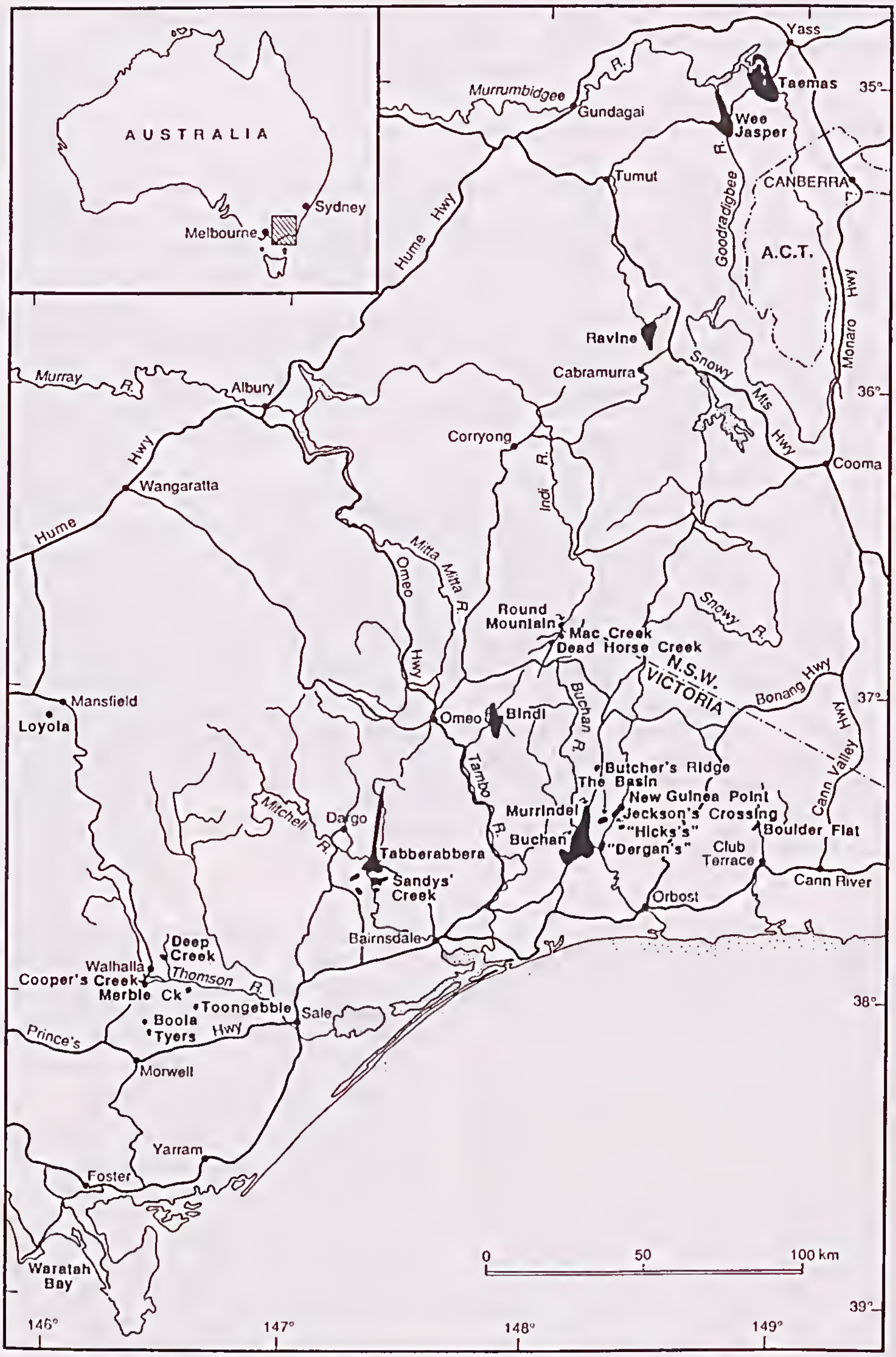


Fig. 1. Location of principal Early Devonian sequences in south-eastern Australia including late Pragian–Emsian sequences investigated for this report.

1988: 513–521; Mawson & Talent 1989: 227) but, in the past two decades, no new conodont data have been provided for the interval about the Pragian–Emsian boundary. The extraordinarily low yields of generally nondescript conodonts obtained in early investigations of the Buchan Caves Limestone (Philip 1966) and Cavan Formation (Pedder et al. 1970) were uninviting. These low yields are clearly to be connected with very shallow environments, such as those represented by the dolomitic sequence at the base of the widespread Buchan Caves Limestone. These include intermittent supratidal environments indicated by fenestral fabrics. Nevertheless, in view of the excellent sections in so many areas, various south-eastern Australian sequences were deemed to have potential value for providing information not only on T/R events but on shallow water conodont biofacies as well.

The present investigation was initiated in response to an appeal from the International Subcommission on Devonian Stratigraphy for more data on conodont evolution about the Pragian–Emsian boundary. It had three other foci:

1. To provide a more precise date or dates for the major transgressive event (or events) indicated by the base of the Buchan Caves Limestone and by the Cavan Formation.
2. To attempt greater precision in stratigraphic alignment of various Pragian/Emsian limestone-bearing units in south-eastern Australia.
3. To obtain more information on the pattern of conodont biofacies at that time.

The following abbreviations are used for conodont genera throughout the text, on figures and tables: *A.* = *Amydrotaxis*, *B.* = *Belodella*, *D.* = *Drepanodus*, *E.* = *Eognathodus*, *I.* = *Icriodus*, *N.* = *Neopanderodus*, *O.* = *Oulodus*, *Pa.* = *Panderodus*, *Pand.* = *Pandorinellina*, *P.* = *Polygnathus*. Abbreviations used for stratigraphic sections are shown in Figs 2 and 3; additional abbreviations used in figure explanations are TAB for Tabberabbera and BF for Boulder Flat.

SEQUENCES INVESTIGATED: STRATIGRAPHIC BACKGROUND

1. *Cavan Formation*

The Taemas–Wee Jasper area is folded into a broad syncline–anticline–syncline system; the westernmost structure is the Wee Jasper Syncline. Three major Devonian units outcrop within it: the Black Range Group, a c. 2350 m sequence of subaerial to subaqueous acid volcanics and volcaniclastics, passing gradationally upwards into the c. 940 m Murrumbidgee Group (latest Pragian–Emsian), a carbonate sequence with subordinate clastics. The latter, in turn, passes gradationally into the Hatchery Creek Conglomerate, the transition taking place late in the Emsian within the *serotinus* Zone (Mawson & Talent, unpub. data). At least the last 70 m of the Taemas Formation is referable to the *serotinus* Zone (Philip & Jackson 1970, pl. 40, figs 6, 8; Ziegler 1977: 496). We are concerned here only with the Cavan Formation (Browne 1959; Cramsie et al. 1975, 1979; Owen & Wyborn 1979), the lowest unit of the Murrumbidgee Group.

In the Wee Jasper area, the Cavan Formation is gradational from the underlying Sugarloaf Creek Formation, a lithic sandstone–siltstone sequence. Three units are differentiated.

3 (highest). Unit C ("Upper Member"), consisting of mudstones with carbonates decreasing upwards, is 67 m in thickness on our measured section CABL (Figs 2C and 5) at Wee Jasper. The boundary with the overlying Majurgong Formation is gradational, being arbitrarily delineated by the last outcropping bed of limestone. At Cavan, in the Taemas area, the "Cavan Bluff Limestone" is overlain by "15 m of yellowish limestone with shale interbeds" followed by 7 m of massive limestone (Owen & Wyborn 1979), but there is no especially prominent limestone immediately above the "Cavan Bluff Limestone" (Unit B) at Wee Jasper. Other workers, therefore, might prefer to regard Unit C as being part of the Majurgong Formation, as was done by Pedder et al. (1970).

2. Unit B ("Middle Member") consists at Cavan of 9 m of laminated algal limestone overlain by 42 m of massive to well-bedded limestone (the "Cavan Bluff Limestone Member"). On our measured section CABL (Figs 2C and 5) at Wee Jasper there was only 18 m of massive limestone. Unit B is often highly fossiliferous and outcrops conspicuously.

1 (lowest). Unit A ("Lower Member") consists, in the Cavan area (Owen & Wyborn 1979), of 30 m of laminated grey and brown mudstones with minor, generally thinly bedded limestones. If, following Owen & Wyborn, we place the lower boundary of this unit at the first limestone, the thickness on our measured section CABL (Figs 2C and 5) at Wee Jasper is about 92 m.

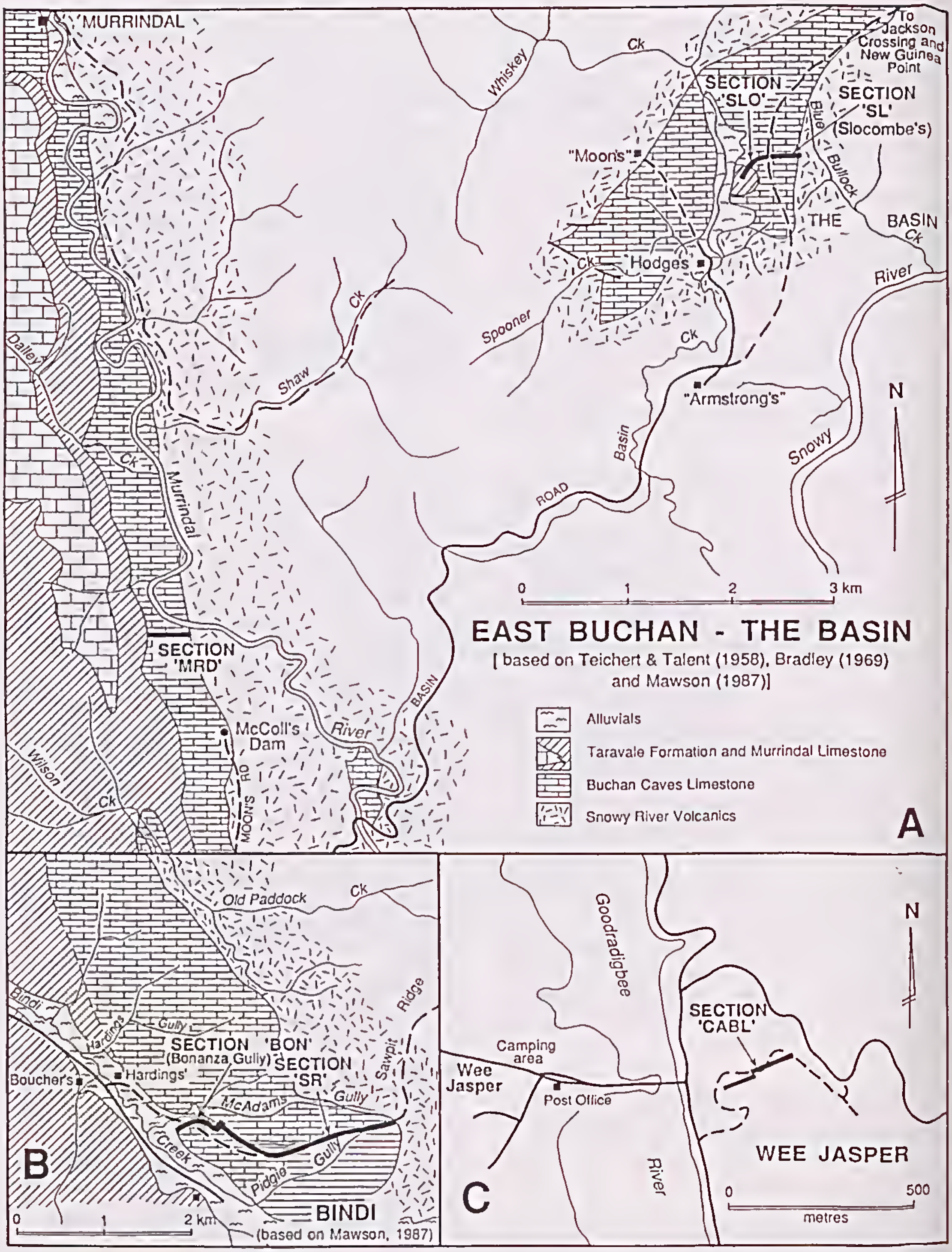


Fig. 2. A, the Buchan Group at The Basin and East Buchan showing location of sections sampled (prefixes SL and MRD). B, the Buchan Group at Bindi showing location of sections sampled (prefixes SR and BON). C, the Cavan Formation at Wee Jasper showing location of section sampled (prefix CABL).

2. *Buchan Caves Limestone*

The Buchan Caves Limestone (Talent 1956; Teichert & Talent 1958; Bradley 1969; Mawson 1987a) is a c. 210 m thick late Early Devonian transgressive carbonate unit structurally preserved in eleven significant and several tiny outcrop tracts in eastern Victoria (Fig. 1), principally in the Buchan–Murrindal, Bindi and Gillingal areas, at The Basin and in tracts along the Snowy River Valley and along Limestone Creek in the headwaters of the Indi River. Minimal thickness is about 67 m in the vicinity of the ruins of the former Slocombe homestead at The Basin; the maximum thickness measured was 236 m on our MRD section, but considerably thicker sequences are inferred to have existed in the Back Creek area of East Buchan.

The lower Buchan Caves Limestone consists generally of unfossiliferous dolomites and dolomitic limestones weathering to buff, dull grey or even earthy yellow with a characteristic pattern resembling criss-crossing knife incisions. This sequence is only 8 m thick in the outcrop tract near the junction of Dead Horse and Limestone creeks (Fig. 3A) but may exceed 35 m in the Back Creek area of East Buchan. The dolomitic sequence passes upwards into calcarenites and calcisiltites making up the bulk of the Buchan Caves Limestone. These tend to be monotonous and yield low-diversity faunas with brachiopods, almost invariably disarticulated and dominated by *Spinella* (Talent 1956). Apart from *Chalcidophyllum recessum* (Hill), occurring in abundance in a few beds, especially in the upper Buchan Caves Limestone, rugose corals are sparse. Tabulate corals, principally species of *Favosites*, *Syringopora* and *Thamnopora*, tend to be more common and diverse (Hill 1950). Oncolitic horizons in this sequence at Buchan (Talent 1956) and Bindi, coupled with absence of bryozoans, trilobites and even a dearth of molluscs, except for small nondescript forms tending to occur as nuclei of oncoliths, are consistent with very shallow water, abnormal as regards circulation and/or salinity.

More diverse faunas occur in the uppermost third of the Buchan Caves Limestone. Occasional horizons, usually dark grey calcilutites and calcisiltites, have produced abundant ostracodes (Krömmelbein 1954), bivalves (Talent 1956; P. A. Johnston, unpub.), bellerophontids and occasional cephalopods (Teichert & Glenister 1952).

Diverse silicified faunas have been found in two areas: a gastropod–bivalve fauna near the top of the Buchan Caves Limestone in the vicinity of Slocombe's Cave at The Basin; and a rather diverse brachiopod fauna near the top of the formation on the ridge extending eastwards from Chisholm homestead, about 1.8 km south of Murrindal. Such relatively high diversity faunas are exceptional departures from the prevailing low diversity believed to have been connected with very shallow marine conditions that extended regionally (the Buchan–Indi–Combienbar Shelf of Talent 1969).

The Buchan Caves Limestone is a notably high purity carbonate sequence. Local developments of shales, calcareous mudstones and nodular limestones have been noted in excavations made during fencing in Spooner Creek, The Basin, and were formerly well-expressed in low road cuttings on the Buchan–Orbost road about 1.2 km south-east of the Back Creek bridge. The last of these, focus of Talent's (1956) Cameron Member, was largely obliterated by road realignment in the late 1960s. It had been interpreted (mapping by V. N. Cottle, in Teichert & Talent 1958) as a fault-bounded sliver of Taravale Formation. These two occurrences produced well-preserved brachiopod–coral faunas with an abundance of ostracodes in the latter. Such occurrences were obviously rare in the otherwise monotonous carbonate platform.

The most substantial developments of high diversity brachiopod faunas with high articulation-index occur in what we have previously referred to (Mawson 1987a; Talent & Yolkin 1987; Talent 1989) as the upper Buchan Caves Limestone at Bindi, especially in Pidgic, Bonanza and McAdam's gullies (for localities see Mawson 1987a, Fig. 3) in a distinctive, recessive, thinner bedded, occasionally argillaceous unit high in the *dehiscens* Zone, overlain by a unit of more thickly bedded limestones. We have inferred the thinner bedded sequence to reflect a deepening or transgressive event (Talent & Yolkin 1987; Talent 1989), corresponding to the transgressive event at Buchan expressed as the abrupt change from Buchan Caves Limestones to Taravale Formation mudstones and nodular limestones characterized by pelagic faunas—dacryoconarids, ammonoids (rare) and conodonts typical of the Polygnathid Biofacies.

Webb (1992) has suggested extending use of the term Murrindal Limestone into the Bindi area, applying it to a unit we informally referred to as the "Shanahan Limestone" (Mawson 1987) and to the upper of the two transgressive cycles we discriminated within what we have previously referred to as the Buchan Caves Lime-

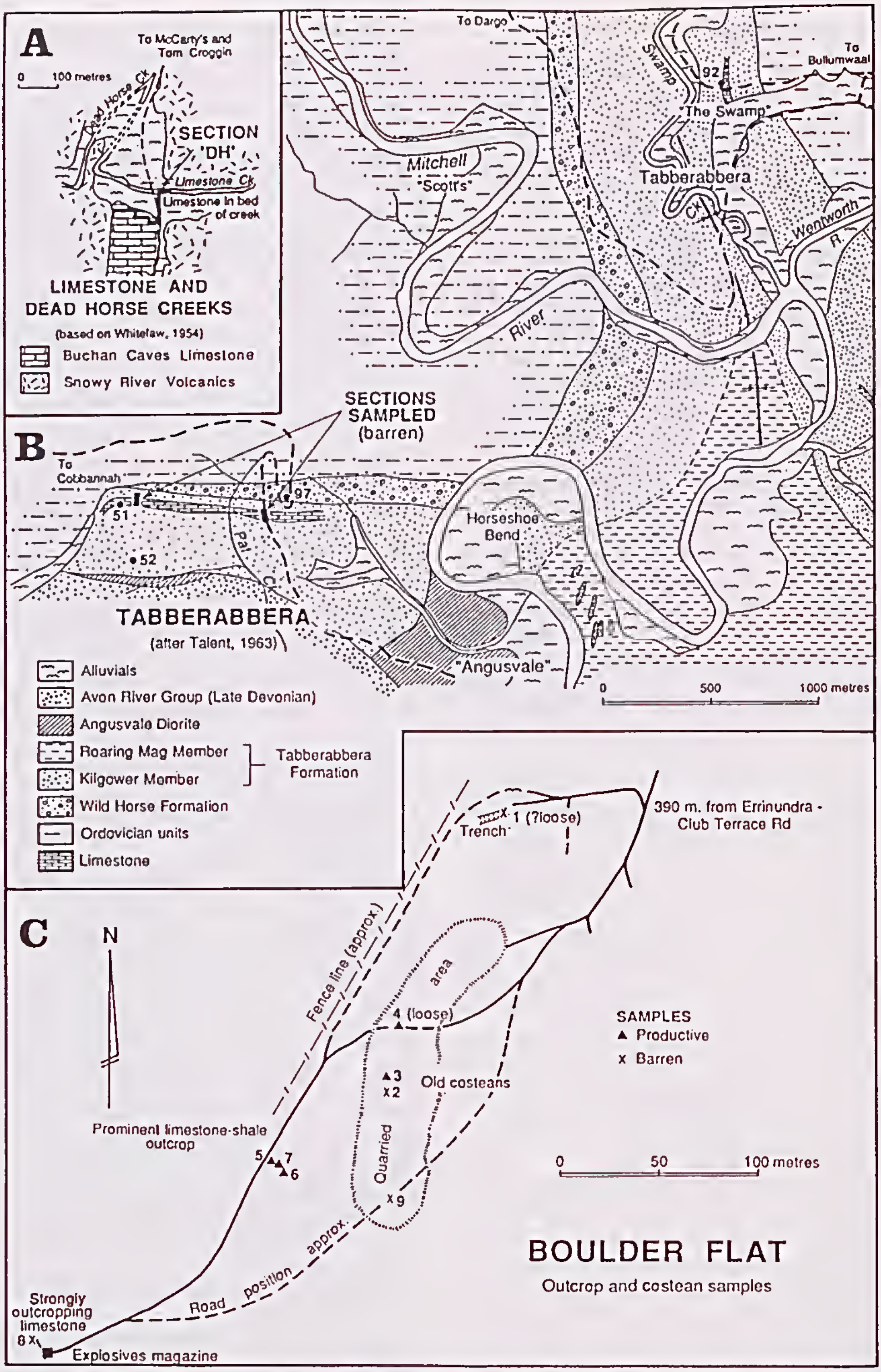


Fig. 3. A, the Buchan Group at the junction of Dead Horse and Limestone creeks showing section sampled (prefix DH). B, location of stratigraphic sections (both barren) and productive spot samples at Tabberabbera (prefix TAB). C, location of spot samples at Boulder Flat (prefix BF).

stone at Bindi. We believe Webb's suggestion to have merit, particularly as we now know that the northern part of the Buchan Group at Bindi is fundamentally synclinal and that the "Shanahan Limestone" is a repeat by folding of the uppermost part of the Buchan Caves Limestone (or Murrindal Limestone *sensu* Webb), truncated to the west by the Indi Fault.

Spot sampling by Philip (1966) of the Buchan Caves Limestone for conodonts at Buchan some 25 years ago gave disappointing results; no polygnathids were obtained. Since then the conodont faunas of the uppermost part of the Buchan Caves Limestone at Bindi and beds about the Buchan Caves Limestone–Taravale Formation boundary at Murrindal have been documented (Mawson 1987a), but there are no published data on the sequence of conodonts through the rest of the Buchan Caves Limestone.

3. *Loyola*

Conodonts have been described using single-element taxonomy (Cooper 1973) from four limestone bodies outcropping at Loyola, 11 km south-west of Mansfield and 200 km north-east of Melbourne. The faunas are significant as they include four specimens of a form, *"Spathognathodus" trilinearis*, recognized as new by Cooper, as well as two incomplete and poorly preserved specimens of *Polygnathus* not specifically identified by him but thought to be probably *P. dehiscens*. As noted below, we believe the latter two specimens more likely to be *P. pireneae* Boersma; we refer *"S". trilinearis* also to *Polygnathus*, believing it to be good evidence for derivation of the genus from *Eognathodus*.

The specimens of *P. trilinearis* (Cooper) and *P. pireneae* were not obtained from the same lens. The former came from a 36 kg sample from the quarry at the Old Lime Kiln, about 750 m north-west of, and conceivably stratigraphically beneath, the limestones outcropping in Griffiths's Quarry, the source of the specimens of *P. pireneae*. The area has few and generally poor outcrops. Despite this, the geometry of a belt of fossiliferous grits and conglomerates outcropping c. 500 m south-west of the quarries (Cooper 1973, fig. 1) indicates that the matrix of the two limestone occurrences, as well as that of the Cummins Road limestone outcrop, may be assumed to be stratigraphically equivalent or very nearly so. The limestone lenses, however, may be olistoliths (Conaghan et al. 1976: 529) and thus conceivably divergent in age. We cannot be sure, therefore, from previously available information from Loyola, whether the time-range of *P. trilinearis* overlaps with that of *P. pireneae*.

4. *Boulder Flat*

Limestones overlying a mixed volcanic–sedimentary succession were reported by Thomas (1949) from Boulder Flat in the Errinundra valley, 15.1 km by road north of Club Terrace in eastern Victoria. The outcrops about Boulder Flat were examined by one of us [JAT] in 1954. The marine sediments below the limestones, shown by Thomas (1949, loc. 3) as containing "*Tentaculites* and spirifers, etc.", produced *Spinella* too badly sheared for specific identification but bearing the spinose microsculpture characteristic of the genus. Poorly preserved favositids, rugose corals and cross-sections of brachiopods consistent with *Buchanathyris* and *Spinella* but too badly preserved for generic identification were obtained from the limestones. Thomas's correlations were therefore accepted (Talent 1965) but were subsequently challenged (Ramsey & VandenBerg 1986) on lithological grounds and on the basis of identifications (Pickett 1984) of the conodonts *Amydrotaxis druceana* (Pickett) and *"Delotaxis" tenuistriata* Pickett from the limestones. The entire volcanic–sedimentary sequence was referred to as the Errinundra Group (Ramsey & VandenBerg 1986; VandenBerg 1988; VandenBerg et al. 1990) and interpreted (VandenBerg 1988) as a "structural remnant of a small rift-like extensional basin in which shallow marine sedimentation was contemporaneous with silicic volcanism". The Errinundra Group was viewed as consisting of two formations: the Bungywarr Formation below overlain by the Boulder Flat Limestone. The former was construed as consisting of two members: the Blackwatch Volcaniclastic Member above and the Bola Sandstone Member below.

The limestones at Boulder Flat are dolomitic, mineralized (barite and sulphides) and often extremely recrystallized and stylobrecciated. Outcrops are poor and have been made worse by bulldozing for barite. Unaware that work was being undertaken by VandenBerg (in Pickett 1984), we repeatedly sampled the limestone area at Boulder Flat (Fig. 3C) in the early 1980s.

5. *Waratah Bay*

The Bell Point Limestone (Fig. 4), outcropping in three areas on the west side of Waratah Bay, Victoria, has been correlated with the Buchan Caves Limestone and inferred to be an expression of the same transgressive event (Talent

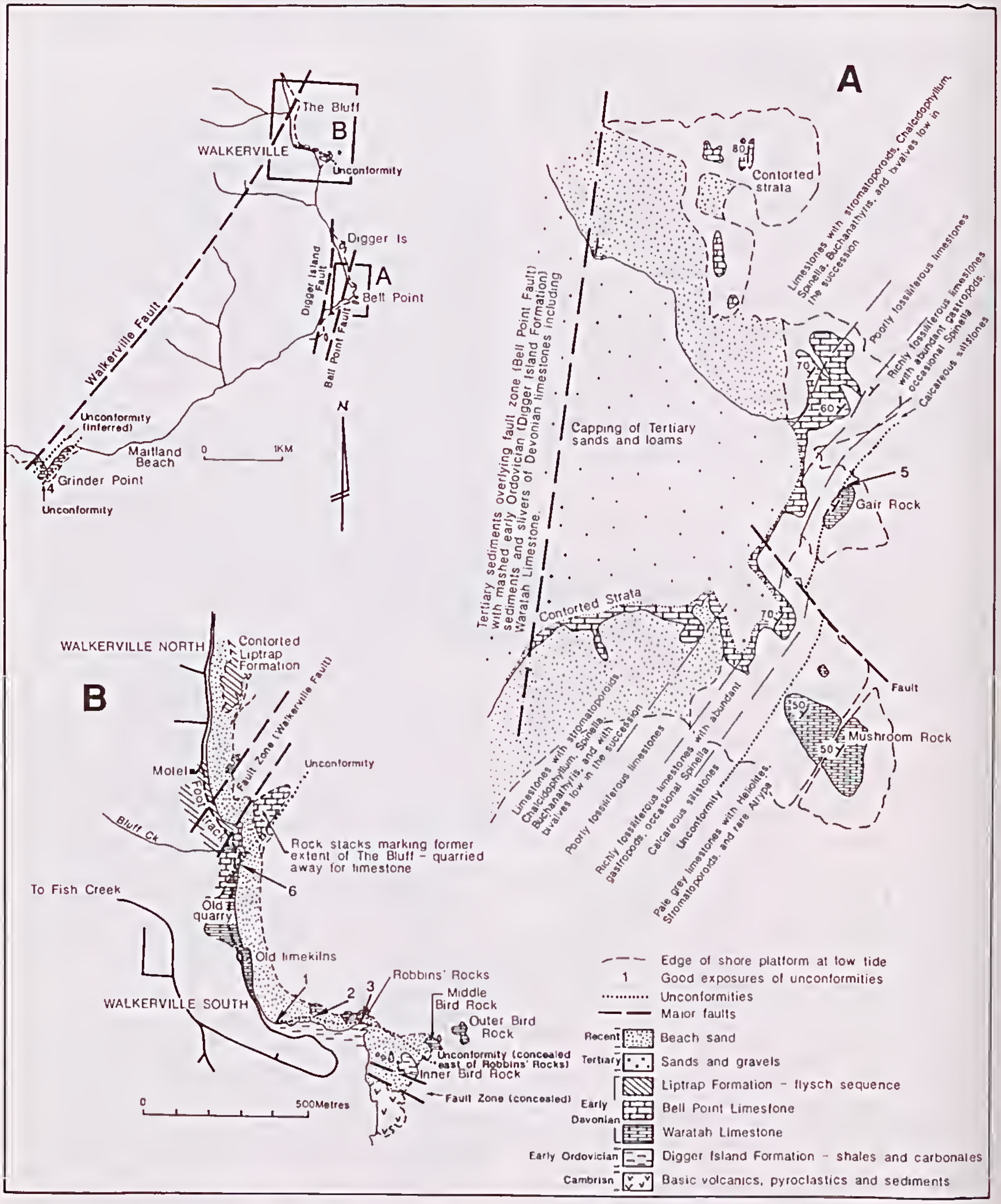


Fig. 4. Early Devonian carbonate units and unconformities on the west side of Waratah Bay (from Talent 1989, fig. 5, with corrections; based on Talent 1955). Points 1–3 are areas where the unconformity between the Bird Rock Member of the Waratah Limestone and strongly jointed dolomites of the Early Ordovician Digger Island Formation is well expressed. At point 4 the same unconformity, but of Waratah Limestone on a Cambrian volcanic–sedimentary succession, is superbly expressed. Point 5 shows the unconformity between the Bell Point and Waratah limestones.

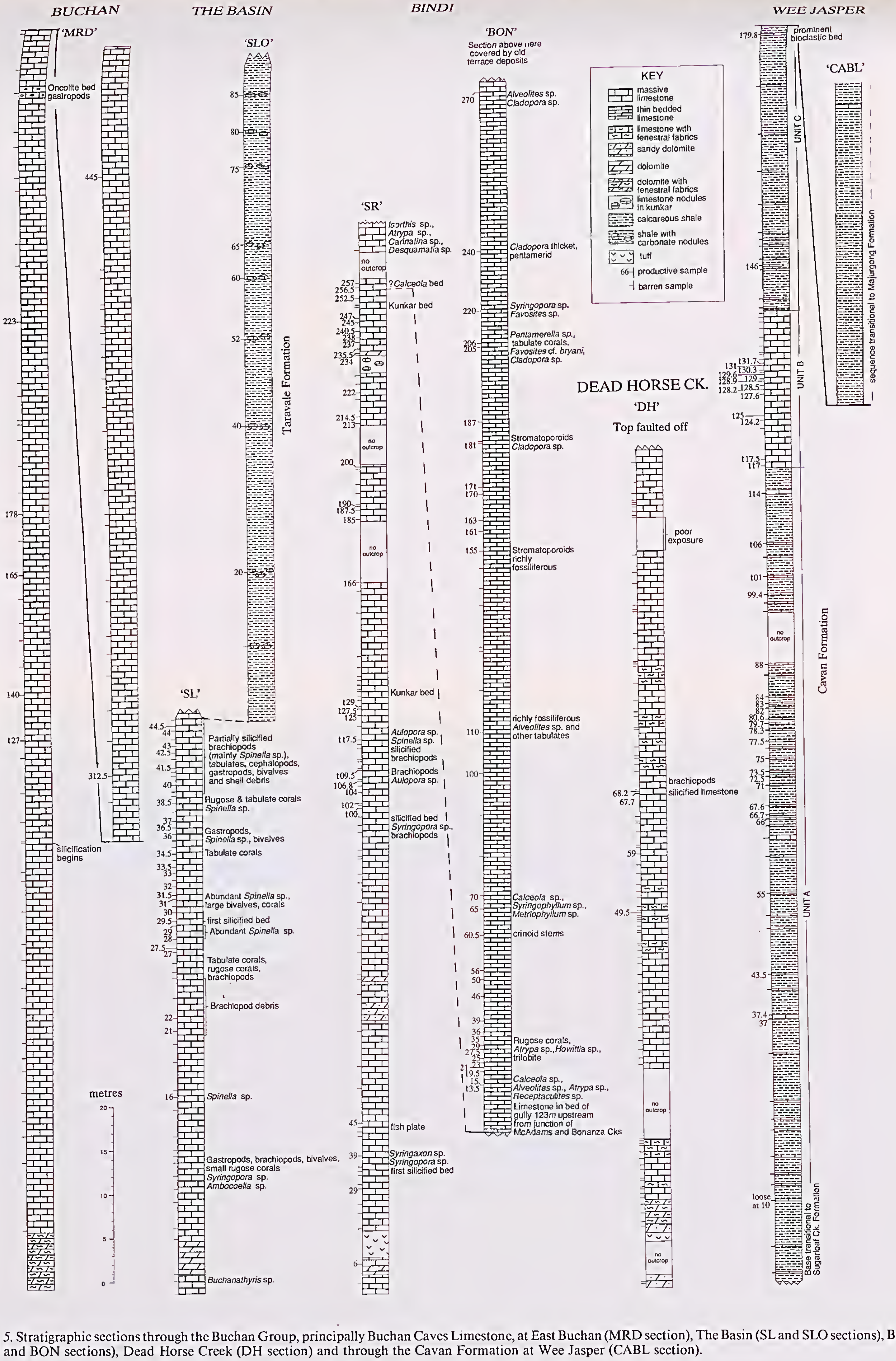


Fig. 5. Stratigraphic sections through the Buchan Group, principally Buchan Caves Limestone, at East Buchan (MRD section), The Basin (SL and SLO sections), Bindi (SR and BON sections), Dead Horse Creek (DH section) and through the Cavan Formation at Wee Jasper (CABL section).

1955, 1965, 1989). The limestones at Waratah Bay were sampled for conodonts by J. C. Argent (1971) within the framework of Talent's (1955) unpublished mapping. Of Argent's samples, 81 proved productive, 36 yielding forms of *Eognathodus*; most others yielded forms of no great correlative significance, and numerous samples were barren. A brief comment was made on some of Argent's identifications by Talent (1989). As a published version of Argent's dissertation has now appeared (Bischoff & Argent 1990), additional comment follows.

1. Talent (1955, 1965, 1989) differentiated between the Waratah Limestone and the unconformably overlying Bell Point Limestone, the former including the Bird Rock and Kiln Members proposed by Teichert (1954). When originally proposed, the Bird Rock Member included a poorly bedded, strongly jointed, pale grey dolomitic sequence outcropping on the foreshore cliffs behind Robins' Rocks [= Robin Rock of Bischoff & Argent]. Despite lack of fossil evidence (samples we have taken for conodonts have proved barren), this sequence is now referred on lithological grounds to the Early Ordovician Digger Island Formation (Talent 1989). The angular unconformity between it and the overlying orange-buff basal sequence of the lower Waratah Limestone is clearly displayed as a thin, basal, pebbly interval. If this restriction in definition is accepted, and it was the fossiliferous section that was clearly intended by Teichert (1954, and in Hill 1954) for his Bird Rock Member, Bischoff & Argent's (1990) "Lower Grinder Member" is more or less a synonym.

2. The unconformity at the top of Bischoff & Argent's (1990) "Mushroom Rock Member", beautifully expressed on the west flank of Gair Rock at Bell Point (Talent 1955, 1965, 1989) is, for us, the same unconformity as the one readily identifiable at the top of Teichert's Kiln Member in the coastal section between Walkerville South and Walkerville North (see Fig. 4). Bischoff & Argent's "Mushroom Rock Member" is therefore an approximate synonym of Teichert's Kiln Member.

6. *Tabberabbera*

The Wentworth Group is a predominantly clastic Early Devonian sequence outcropping in the watersheds of Sandys Creek and the Wentworth and Mitchell rivers in east-central Victoria (Talent 1963). The profound angular unconformity at Tabberabbera between the marine Early Devonian Wentworth Group and the nearly flat-lying non-marine Late Devonian Avon River Group is the typical expression of what has long been termed the Tabberabberan Orogeny (Andrews 1938; Talent 1963, 1965). Talent (1963) suggested that the youngest unit of the Wentworth Group, the Roaring Mag Member of the Tabberabbera Formation, could be approximately correlative with the Buchan Caves Limestone; the underlying Kilgower Member of the Tabberabbera was believed to be significantly older.

INTERPRETATION OF CONODONT DATA

To obtain the results presented here, more than 5 tonnes of samples were collected, mostly along measured stratigraphic sections (Fig. 5), and were partially acid-leached; the sources of 551 of these samples and their productivities are listed in Table 1. Positions of stratigraphic sections are shown in Figs 2 and 3. Positions of horizons sampled, productive and barren, are indicated on the stratigraphic columns in Fig. 5, with additional information for the BON section, particularly offsets, shown in Fig. 6.

Among the numerous 5–10 kg spot samples were a c. 200 kg sample from McColl's Dam, east of Buchan (Fig. 2A) and c. 100 kg samples from localities 92 and 97 at Tabberabbera (Fig. 3B) and from the limestone at the junction of Sandys Creek and the Mitchell River (Easton 1938; Talent 1963), 6 km south of Tabberabbera. In general, samples that proved barren after leaching 1 or 2 kg were not subjected to further

LOCALITY	Number of samples taken	No. of samples with conodonts
CABL stratigraphic section	81	39
SL stratigraphic section	58	25
SR stratigraphic section	91	31
BON stratigraphic section	41	31
MRD stratigraphic section	71	7
DH stratigraphic section	94	4
New Guinea Point	9	3
Basal sequence, Jackson's Crossing	12	0
Heath's Quarry exclusive of Taravale Fm.	3	0
Cameron's Quarry	6	2
Cameron Member	10	7
Basal sequence, Buchan-Orbost Rd., west of East Buchan bridge	17	0
Boulder Flat	9	5
Tabberabbera	c. 43	3
Top 1m of Buchan Caves Limestone overlooking The Pyramids	6	0

Table 1. Number of samples collected and processed for conodonts, and number of productive samples.

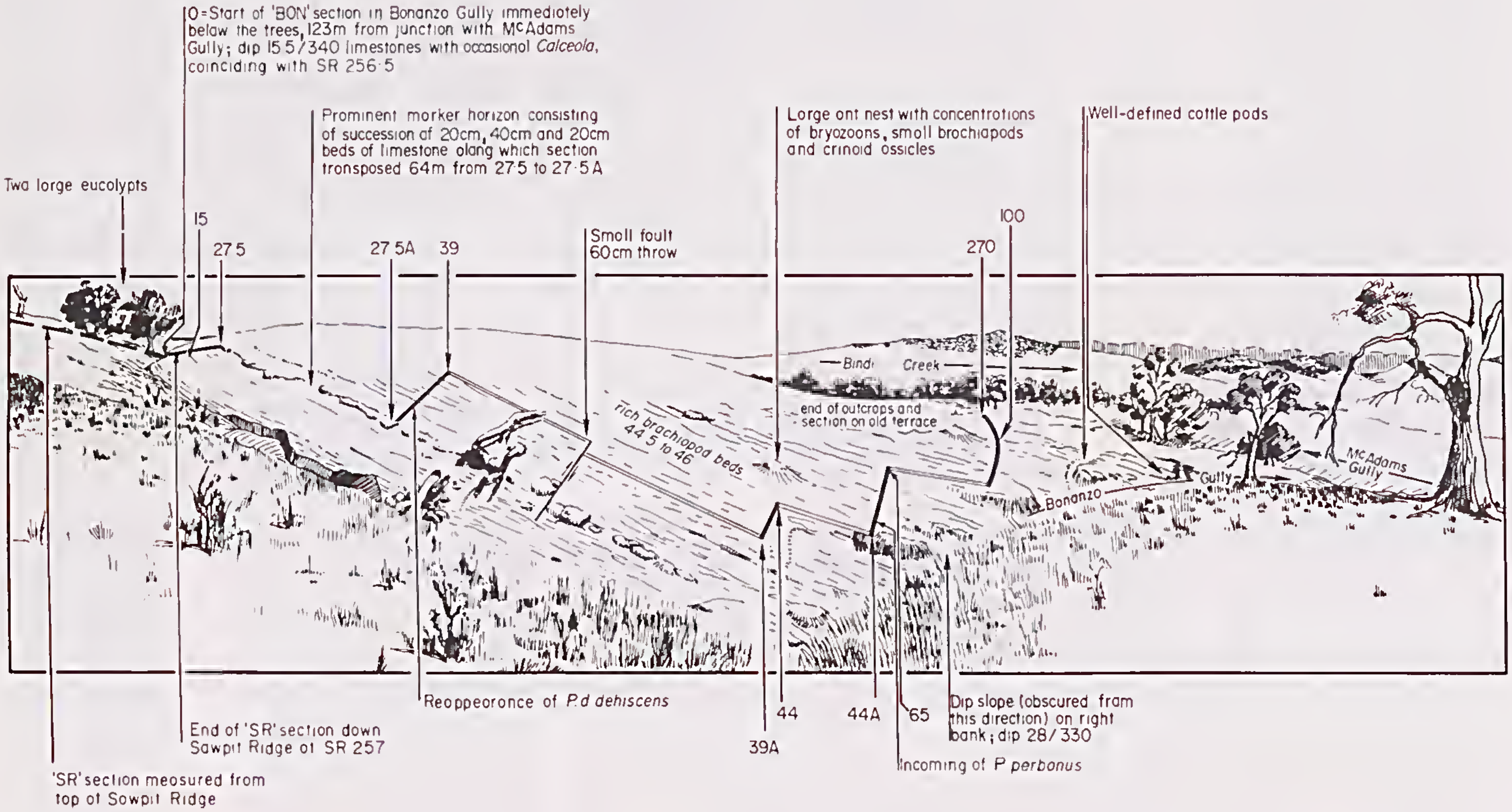


Fig. 6. Panorama (compiled from photographs) of the highly fossiliferous left bank of Bonanza Gully, Bindi, showing position of end of SR section measured down Sawpit Ridge, location of BON section, and positions of offsets along marker horizons. Section BON is located entirely within highly fossiliferous upper Buchan Caves Limestone. Numbers are sample numbers.

solution. The remaining 150 productive samples were generally leached to completion. Illustrations of the conodonts recovered are arranged (Figs. 7–13) according to the sequence of discussion, locality by locality, though with similar forms grouped for comparison.

The overall low productivity and low diversity, apart from the "marginal Polygnathid Biofacies" in the BON section (see below), are interpreted as being connected with the extreme shallowness of most of the environments sampled. The low diversity and high proportion of barren or unhelpful samples has resulted in a measure of imprecision in the conclusions presented below.

As the results obtained concern correlations about the Pragian–Emsian boundary, some comment is appropriate on conodont zonation through the late Pragian and earliest Emsian. In 1989 the International Commission on Stratigraphy ratified the proposal of the Subcommission on Devonian Stratigraphy (SDS) to fix the base of the Emsian at the incoming of *Polygnathus dehiscens*, with the global stratotype being a section in Zinzilban Gorge in the Uzbek Republic. In this section the evolution of *P. pireneae* into *P. dehiscens* has been documented (Yolkin et al. 1989). The *dehiscens* Zone is thus the basal zone of the Emsian, and an interval characterized by the ancestral form *P. pireneae* is thus indicative of latest Pragian.

Conodont faunas from the Road River and Old Camp formations and the Salmontrout Limestone of east-central Alaska enabled Lane & Ormiston (1979) to refine the conodont zonal scheme for the Pragian. They demonstrated the utility of three intervals in the Pragian, a redefined zone of *Eognathodus sulcatus*, an intermediate zone of *E. sulcatus kindlei* (formerly the *E. sulcatus* n. subsp. Zone of Klapper 1977: 41) and, as youngest interval, a zone of *P. pireneae*. The lower boundary of the *pireneae* Zone was defined at the incoming of *P. pireneae*.

Although *P. pireneae* has been identified in faunas from many sequences, e.g. Bathurst Island (McGregor & Uyeno 1972), Spanish central Pyrenees (Boersma 1974), Germany (Al Rawi 1977), Alaska (Lane & Ormiston 1979; Savage et al. 1985) and south-eastern Australia (herein), there are few sections where evolution of *P. pireneae* to *P. dehiscens* and overlapping ranges of the two forms can be demonstrated. The Zinzilban section in Central Asia (Yolkin et al. 1989) is elegant in this regard. The dearth of such sequences seems to be connected with a major regression event, discussed below, during part of the *pireneae* interval. Our contention that *"Spathognathodus" trilinearis* Cooper should be referred to *Polygnathus* means there are at least two forms of the genus in the late Pragian. More precise understanding of the *pireneae* Zone requires further study of the evolution and precise temporal relationships of the earliest forms of *Polygnathus.*

1. *Cavan Formation (Wee Jasper)*

Conodont data presented in Table 2, although sparse, show *P. pireneae* to occur through a 5.9 m interval from 58.3 to 64.2 m above the base of the CABL section measured at Wee Jasper (Fig. 2C), in samples 69.6 through to 75. In sample 72.5, from 35 m below the base of the strongly outcropping "Cavan Bluff Limestone Member" [62.1 m above the base of the section], *P. dehiscens dehiscens* makes its first appearance. Thus, using the criterion suggested by SDS, we place the Pragian–Emsian boundary provisionally at this level.

The polygnathids and pandorinellinids in the CABL section occur in thinly bedded limestones, the association possibly indicating deeper water than for the various sections of Buchan Caves Limestone sampled for this study. These elements disappeared with the shallowing event indicated by accumulation of the richly coralline (Pedder et al. 1970) "Cavan Bluff Limestone Member"; in this unit the conodont fauna is dominated by ozarkodinans, principally *O. buchanensis* and *O. pseudomiae*. These have no particular stratigraphic importance other than that they arise in the *pireneae* Zone and are common within faunas of *dehiscens* age.

2. *Buchan Caves Limestone*

The Taravale Formation is preserved in only three areas, all synclinal: at The Basin, at Bindi and in the Buchan–Murrindal area. Sections through the Buchan Caves Limestone from the Snowy River Volcanics to the base of the Taravale Formation were accordingly sampled (5–10 kg samples at approximately 1–2 m intervals) in each of these areas (Fig. 2A, B). Outliers of Buchan Caves Limestone occur in the lower reaches of Limestone Creek (Whitelaw 1954, VandenBerg et al. 1981, 1984) in the headwaters of the Indi (= Murray) River. Because the basal sequence of the Buchan Caves Limestone is superbly exposed in Limestone Creek just

Metres above base of 'CABL' section		8.3	24.1	24.5	34.4	43.3	57	57.6	58.3	60.8	62.1	62.7	64.2	65.9	66.9	67.8	68.5	69.7	70.4	71.2	74.3	83.3	84.6	88.5	94.8	97.3	97.6	102.9	103.5	105.5	106	106.3	106.4	106.7	107.3	107.7	108.2	108.7	125	151.7	
Sample number		10	37	37.4	43.5	55	66	66.7	67.6	71	72.5	73.4	75	77.3	78.3	79.7	80.6	82	83	84	88	99.4	101	106	114	117	117.5	124.2	125	127.6	128.2	128.5	128.9	129	129.6	130.3	131	131.7	146	179 8	TOTALS
Oulodus murrindalensis	Pa														1																										1
	Pb																																	1							1
	M					1														1																					2
	Sa					1					1						1																								3
	Sb									1		1			1																							1			4
	Sc			1																																					1
Polygnathus d. dehiscens	Pa										1								2																						3
P. d. abyssus	Pa												2						1			3																			6
P. pireneae	Pa								1	1		1	1																												6
Ozarkodina buchanensis	Pa					3	2		1		1		4	1	6	3	2	1	1	3	2		1				2	1	3	2			1			1		1	1		43
O. lineans	Pa									1		1			1																										3
O. prolata	Pa																1				2																			1	4
O. pseudomiae	Pa						4				1		4		3	2	3		4	3	2	1	1		2		1	1	2	2	2				2			2			42
O. selli	Pa																1																								1
O. sp. A.	Pa									1																															1
Pandorinellina e. philipi	Pa								1	4		1																													6
Coelodontus sp.			1			2																																			3
Drepanodus sp.		1				2											1																								4
Non-platform elements	Pb		1		1	2		1	1		5		3	2	1		2	1	1	2	7	2		1			1		1	1						1		2	1		40
	M					1	1				3	2	2			1							1	1	1				1	2								1			17
	Sa																				1	1	1		1																4
	Sb						1			1	3		3	2		2				1	1									1		1	1						1		18
	Sc						1		1	2	6		2		1			1		1	2				1	1		1	2				1			1	3	1			28

Table 2. Distribution of conodont elements in section CABL through the Cavan Formation, Wee Jasper, New South Wales.

Metres above base of 'SL' section		22.5	30	31.5	39	39.7	40.5	42	42.7	43.5	44	45.7	46.5	48	48.7	50.3	52.5	53.2	54	56.2	58.5	60.7	62.2	64.5	65.2	
Sample number		16	21	22	27	27.5	28	29	29.5	30	31	31.5	32	33	33.5	34.5	36	36.5	37	38.5	40	41.5	42.5	44	44.5	TOTALS
Oulodus murrindalensis	Pb																							1		1
	Sa												1								2					3
	Sc												1													1
Ozarkodina buchanensis	Pa	1			23	5	10	4	2				26	8		1		4	2	4	11	2		30	1	134
O. lineans	Pa			1				1					2	1										1		6
O. prolata	Pa												6	3												9
O. sp. A.	Pa				1																					1
O. pseudomiae	Pa				1		3	1	2				7	5	3		3		1	1				8		36
O. sp. indet	Pa										1															1
Panderodus unicostatus	M		2																							2
Non-platform elements	Pb				5		5	2		1		2		3	2		1				1	1		12		35
	M				2								2		1											5
	Sa				2																					2
	Sb		1			1	2					1	1		1						1		1			9
	Sc			1	7	1	5	1					1	2	1			1			1					21

Table 3. Distribution of conodont elements in section SL through the Buchan Caves Limestone at The Basin.

upstream from Dead Horse Creek, a section was closely sampled commencing in the bed of Limestone Creek (Fig. 3A).

Though the SL section through the Buchan Caves Limestone at The Basin (Fig. 2A) yielded no polygnathids (Table 3), this may be connected with excessively shallow water and have no age significance. *O. buchanensis*, *O. linearis* and *O. pseudomiae* first appear at 22.5 m, 31.5 m and 39 m respectively above the base of SL. All three species are present at the same stratigraphic level as the first polygnathids, for example in the CABL section at Wee Jasper, but there are no constraining data regarding their first appearances. At 46.5 m, *O. prolata*, not known to occur in horizons of pre-dehiscens age (Mawson 1987a; Bultynck 1989), makes its first appearance; this is consistent with a *dehiscens* age for at least the upper third of the section. The persistently high dolomitic component and thinness of the Buchan Caves Limestone at The Basin relative to sequences elsewhere in the Buchan–Bindi–Snowy River area is taken to be consistent with a topographic high, on the surface of which the Buchan Caves Limestone accumulated.

In the combined SR–BON section measured at Bindi (Fig. 5; Tables 4, 5), *P. dehiscens dehiscens* occurs in a short interval commencing at 64.6 m above the base of the section, and *O. prolata* first appears a further 42.8 m up section. Again, *O. buchanensis* is present from the base of the section, with *O. pseudomiae* appearing only a few metres before *P. d. dehiscens.* The incoming of *P. perbonus* and *P. nothoperbonus* at BON 46–50, 129.6 m above the base of the section, heralds the start of the *perbonus* Zone. In the combined SR–BON section, the transition of *Pand. exigua philipi* to *Pand. exigua exigua* can be traced from true *Pand. exigua philipi* 98.8m above the base of the section, through a transitional form at 107.9 m, to *Pand. exigua exigua* from 110.6 m upwards. Worthy of note is the upper limit of *O. pseudomiae*, 7 m into the *perbonus* Zone, and the loss of *O. buchanensis* just 3.5 m below beds indubitably referrable to the *perbonus* Zone.

The MRD section at East Buchan (Fig. 5; Table 6) was disappointing; only 7 of the 71 samples yielded conodonts. However, the presence of *P. d. dehiscens* 82.5 m above the base of the section indicates *dehiscens* Zone for at least some of the section. Section DH (Table 6), near the junction of Dead Horse Creek with Limestone Creek, yielded elements of *O. linearis* consistent with a *dehiscens* age (Mawson 1987a).

A basal sequence of Buchan Caves Limestone was sampled in the road cutting on the Buchan–Orbost road immediately west of the East Buchan bridge where there are excellent exposures of carbonates interbedded with clastics derived from a volcanic terrane (Talent 1989); all samples proved barren. Another barren basal sequence is well exposed at Jackson Crossing on the left (north) bank of the Snowy River just downstream from the ford; in this area, the Buchan Caves Limestone rests unconformably on Snowy River Volcanics.

O. buchanensis, O. pseudomiae and *Oulodus murrindalensis* were obtained from samples of the "Cameron Member" of the Buchan Caves Limestone 1.2 km east of the Back Creek bridge, East Buchan. Associated with the fauna is a new species of the dacryoconarid *Volynites* apparently derived from *V. velaini* (Munier-Chalmas) and thought (G. K. B. Alberti, pers. comm.) to be consistent with a *pireneae* age or younger. Samples from New Guinea Point (Fig. 1; Table 6) were taken through the middle of the Buchan Caves Limestone outcropping on the New Guinea Point jeep track approximately 1.8 km up the track from the helipad. Spot samples from seemingly low in the Buchan Caves Limestone in the Butchers Ridge and Round Mountain outliers proved unproductive, as did samples from the uppermost part of the Buchan Caves Limestone on "Davidson's Ridge" at Jacksons Crossing.

Because of lack of adjacent outcrop, the limestones in the vicinity of Martin Cameron's Quarry, 6.7 km south-south-west of Buchan, were once thought (Teichert & Talent 1958: 18) to be possibly a carbonate buildup within the Taravale Formation, but closer investigation (Fletcher 1963) showed them to belong to the Buchan Caves Limestone. The limestones at Martin Cameron's Quarry are richly fossiliferous, with stromatoporoids (Ripper 1937), rugose corals and especially tabulate corals dominating the fauna. Despite processing large quantities of limestone relatively free of corals and stromatoporoids, the only conodonts obtained were *O. buchanensis, O. linearis, O. pseudomiae* and *Oulodus murrindalensis.* Of these, *O. linearis* is not known for certain from pre-*dehiscens* horizons.

Limestones in the vicinity of Heath's Quarry in the headwaters of Tara Creek, 6.5 km south of Buchan, have also been construed as part of a carbonate buildup (Teichert & Talent 1958: 16; Talent 1988: 322), but developed within the upper Buchan Caves Limestone. The Heath's

Metres above base of 'SR' section		2.2	10.8	14.6	18.3	54.2	54.9	55.8	57	58.4	58.9	61.9	64.6	65.5	66	79.9	87.3	88.3	89.3	93.2	98.2	98.8	101.7	106.3	106.8	107.4	107.9	108.8	110.6	111	113.2	114.7	114.9	
Sample number		6	29	39	45	100/1	102	104	106.8	109.5	110.5	117.5	125	127.5	129	166	185	187.5	190	200	213	214.5	222	234	235.5	237	238	240.5	245	247	252.5	256.5	257	TOTALS
Oulodus murrindalensis	Pa														1	1																		2
	Pb						1																											1
	M						1																											1
	Sa														3																			3
	Sb															1																		1
	Sc								1			1			1	4																		7
Polygnathus d. dehiscens	Pa												10	1																				11
Ozarkodina buchanensis	Pa	1	1			13	6	1	5	3			2		63	5	39				1	6	2	1			1	1	44	22	1	2	5	225
O. e. excavata	Pa															1																		1
O. linearis	Pa														4		3	2	6		1	1	3		1		1		11	11	1		1	46
O. prolata	Pa																		1							2		2	49	18	5	5		82
O. pseudomiae	Pa					2		1		1					10											1								15
Pandorinellina e. exigua	Pa																												19	9	2	4	13	47
Pand. e. philipi	Pa				1										?2			1	4	5	1	1								3				18
Transitional to *P. e. exigua*	Pa																										1		6	6				13
Panderodus unicostatus	M														15		8			1	3	2	2	1		1		1	220	22	3		6	285
Non-platform elements	Pb			1		3		1	1	1			2		9	2	12		1	1	2	2	2					2	12	12	2			68
	M								1				2						2										4	2	1	1	1	14
	Sa						1						1		1		5	1	1			1								2	1			14
	Sb						1	1					1		3		1	1				2								2				12
	Sc		1			1	2		2						1		10	3	4	1	3	4							15	12	2			61

Table 4. Distribution of conodont elements in section SR through the Buchan Caves Limestone along Sawpit Ridge, Bindi.

Metres above base of 'BON' section		114.7	119 - 119.5	119.5 - 120.9	121.5 - 122	122.6 - 123.4	123.9 - 125	126.1 - 127	129.6 - 131.5	131.5 - 132.5	132.5 - 136.4	136.4 - 138.6	138.6 - 140.9	155 - 159.7	180.8 - 183.6	184.6 - 187.9	188.3 - 192.6	195.8 - 204.3	204.7	211.3 - 220.7	220.7 - 234.8	
Sample number		0	13.5 - 15	15 - 19.5	21 - 23	25 - 27.5	29 - 35	36 - 39	46 - 50	50 - 56	56 - 60.5	60.5 - 65	65 - 70	100 - 110	155 - 161	163 - 170	171 - 181	187 - 205	206	220 - 240	240 - 270	TOTALS
Oulodus murrindalensis	Pa								1													1
	M					2			2													4
	Sb					1																1
	Sc					1			2	1			1	1								6
Polygnathus dehiscens dehiscens	Pa						1	6	3													10
Transitional to *P. nothoperbonus*	Pa							4	4											1		9
P. nothoperbonus	Pa								7	1	2	3								2		15
P. dehiscens abyssus	Pa						1	6	9		1	1										18
Transitional to *P. perbonus*	Pa								1		1											2
P. perbonus	Pa								2		3	1				1						7
Ozarkodina buchanensis	Pa		12					2														14
O. excavata excavata	Pa								1													1
O. linearis	Pa		2		5		1	3	1			1		1								14
O. prolata	Pa		6	8	16	7	35	47	29	18	18	39	21			2						246
O. pseudomiae	Pa		2					2				2										6
Pandorinellina exiqua exiqua	Pa	6	49	13	15	9	28	9	9	4	7	1	4		1	6	1		3	7	6	178
Belodella devonica					1						1											2
Panderodus unicostatus	M		7																			7
	S	1	28		2	3	2	4	1	1	2	4	1		2				2	1		54
Non-platform elements	Pb		1	4		2	18	18	12	3	7	11	3			3			1	2	2	87
	M		2			1	1	6	2	3	1					1				1		18
	Sa			1	1	2	1															5
	Sb							1														1
	Sc		58	4	5	7	8	7	18	3	1	3	2			4		1		1	2	124

Table 5. Distribution of conodont elements in section BON through the upper Buchan Caves Limestone commencing at SR256.5 in Bonanza Gully, Bindi.

Quarry limestone body is most unlike the Buchan Caves Limestone elsewhere in eastern Victoria. It is light grey and extraordinarily fossiliferous with a great diversity of stromatoporoids (Ripper 1937), algae and massive, fasciculate and ramose tabulate corals as well as occasional cerioid and phaceloid rugose corals (Hill 1950).

No conodonts were obtained from the massive limestones exposed in the quarry and its immediate vicinity, but limestone nodules from the Taravale Formation outcropping intermittently in the gutter along the access road leading southwards from the quarry produced polygnathids transitional from *P. dehiscens* to *P. perbonus*. A sample 20 m along the gutter from the southernmost outcrop of limestone at the quarry, equivalent to just a few metres stratigraphically (outcrops are poor) above the Buchan Caves Limestone, produced five such specimens. Four specimens of the same transitional form were found previously, about 0.8 km to the north in outcrops along the old track to the site of McRae's former Taravale Homestead, 3 m stratigraphically above the Buchan Caves Limestone (Mawson 1987a, Tables 2 and 5, sample OTRC 5).

If comparison is made with the conodont faunas from samples collected from the entrance cutting to the Buchan Caves Reserve 6.5 km away, the horizon with polygnathids transitional from *P. dehiscens* to *P. perbonus* in the vicinity of Heath's Quarry equates approximately with sample BCE 3 (Mawson 1987a, Table 3), 61.8 m above the base of section BCE. This is equivalent to approximately 114 m above the top of the Buchan Caves Limestone.

If we assume the transitional forms *P. dehiscens* to *P. perbonus* in the vicinity of Heath's Quarry and in the vicinity of the Buchan Caves Reserve occur at approximately the same stratigraphic level, the contrast in stratigraphic position (c. 3 m versus c. 114 m) relative to the top of the Buchan Caves Limestone is far greater than would be anticipated over such a short distance (6.5 km). This is surprising given the relative uniformity in stratigraphy of the Buchan Caves Limestone over so much of the Buchan–Murrindal–Gillingall–Jacksons Crossing area (Talent 1956, 1969). We infer from this that the Heath's Quarry buildup may have had appreciable relief and grown entirely (or perhaps continued growing) long after the transgressive event expressed by the spreading of the Taravale Formation (and the onset of pelagic conditions) over most of the area.

3. *Loyola*

Our sampling in quest of additional data on the occurrences of early polygnathids at Loyola proved unsuccessful, but identifications of other forms we obtained are noted (Table 6). *Polygnathus trilinearis* (Cooper) occurs at the Kiln Quarry whereas *P.* cf. *pireneae* has been found only at Griffiths' Quarry. That such forms may occur in association must rest on evidence from not very well preserved material documented here from Boulder Flat. Better preserved material of *P. trilinearis* occurring in association with indubitable *P. pireneae* has been obtained from a clast in the lower Cunningham Formation 6.2 km north-north-west of Mumbil in west-central New South Wales (Talent & Mawson in prep.)

4. *Boulder Flat*

Five localities we sampled proved productive (Table 6). One of these, locality 5, corresponds to VandenBerg's (in Pickett 1984) productive locality C811; his other productive locality, C810, seems to correspond to our locality 4. All produced polygnathids: four with *Polygnathus trilinearis* (Cooper), three with *P.* cf. *pireneae* Boersma, two of these with both forms associated. Our sampling thus failed to produce evidence of horizons older or younger than the latest Pragian *trilinearis–pireneae* interval, probably not older than the lower part of the Buchan Caves Limestone. Our sampling demonstrates that *Amydrotaxis* (Fig. 9M) can occur in association with *Polygnathus pireneae*; the genus *Amydrotaxis* thus persisted into latest Pragian times.

We were unable to confirm Pickett's (1984) report of *Delotaxis* (= *Oulodus*) *tenuistriata* from Boulder Flat, but indubitable *O. tenuistriata* occurs in association with *P. pireneae* in limestones of the "Coopers Creek Formation" outcropping on the left side of the Tyers River beneath the bridge at grid reference 494805 on 1:25,000 topographic map 8121-1-1 Rintoul Creek. *O. tenuistriata* thus extends from at least the *eurekaensis* Zone (Mawson 1986) through into at least the *pireneae* Zone.

Additionally, data from the Black Watch Member of the Bungywarr Formation (see earlier) at Boulder Flat indicates that the stratigraphically important brachiopod genus *Spinella* extends downwards to at least the *pireneae* Zone.

Evidence to hand is thus consistent with the limestones at Boulder Flat aligning in a general

LOCALITY		EAST BUCHAN 'MRD'								DEAD HORSE CK.	NEW GUINEA POINT			TABBER-ABBERA			BOULDER FLAT					LOYOLA	
Metres above base of section			63	68.7	82.5	89	111.5	152.2	222.5														
Sample No.		McColl's Dam	127	140	165	178	223	312.5	445		3	5	6	97	92	52	3	4	6	7	5	Kiln Q.	Griffith's Q.
Pelekysgnathus sp.	Pa												1								1		
Oulodus murrindalensis	Pb																	3					
	M					1																	
	Sa		1			1					1												
	Sb																	1					
	Sc																	2					
Oulodus sp.	Pa											1		1									
Polygnathus d. dehiscens	Pa				1																		
P. cf. *pireneae*	Pa																1	3		1			
P. trilinearis	Pa													1				2	1	3	4	$\boxed{1}$	
Polygnathus sp.	Pa																						$\boxed{2}$
Ozarkodina buchanensis	Pa	3					2		3			1					1	1			1	$\boxed{3}$	$\boxed{3}$
O. excavata	Pa	3																					
O. linearis	Pb															1							
	Sa									1													
	Sb									1													
O. cf. *optima*	Pa														1								
O. prolata	Pa								9														
O. pseudomiae	Pa	2		1			4		1					cf1								3	2
Ozarkodina sp.	Pa																				1		
Pandorinellina ex. philipi	Pa													1			1		1	7	15		
Pand. s. steinhornensis	Pa													1									
Amydrotaxis sp.	Pa																			1	?1		
	Pb																		1		1		
	Sc																				1		
Belodella devonica																						2	
Belodella resima																1						1 $\boxed{1}$	
Drepanodus sp.																1		1				$\boxed{1}$	
Neopanderodus aequabilis																1				1	1		
Panderodus unicostatus																					2		
Panderodus cf. *valgus*																1							1
Non-platform elements	Pb	2					1	1	2					3		1	1				1	$\boxed{1}$	1
	M								2							1							
	Sa																					$\boxed{3}$	
	Sb	3					1		1										1		2	1	
	Sc	3					1		4			1									2	1 $\boxed{1}$	

Table 6. Distribution of conodont elements in section MRD through the Buchan Caves Limestone at East Buchan, New Guinea Point, in the DH section at the junction of Dead Horse and Limestone creeks, and at Tabberabbera, Boulder Flat and Loyola. Identifications based on Cooper (1973) are shown "boxed".

way with the Buchan Caves Limestone, the underlying sedimentary–volcanic sequence ("Bungywarr Formation") equating with an unspecified portion of the upper Snowy River Volcanics. The principal difference between the sequences in the two areas is that the "Bungywarr Formation" is more marine and less volcanic than typical Snowy River Volcanics sequences to the west. We accordingly follow Thomas (1949) in regarding the fault-preserved sedimentary–volcanic sequence at Boulder Flat ("Errinundra Group") as being best viewed as an outlier of the Snowy River Volcanics–Buchan Group succession rather than being the preserved record of a discrete "small rift-like extensional basin" with carbonate sedimentation commencing significantly earlier than at Buchan, for example.

5. *Waratah Bay*

Though not unexpected from an horizon such as the Bell Point Limestone, we do not accept the identification of the pivotal form *Polygnathus pireneae* Boersma in Argent's sample 163 from the mashed occurrence of *Amphipora*-rich limestones of this unit at The Bluff (= Bluff Member of Teichert 1954). The illustrated specimen (Bischoff & Argent 1990, pl. 3, fig. 14) lacks the medial row of denticles essential for reference to *Polygnathus*. We interpret it as a specimen of *Eognathodus sulcatus* with an oblique crack. Available conodont data thus does not provide precision regarding correlation of the Bell Point Limestone, nor a clear indication as to the time represented by the unconformity between the Waratah and Bell Point limestones.

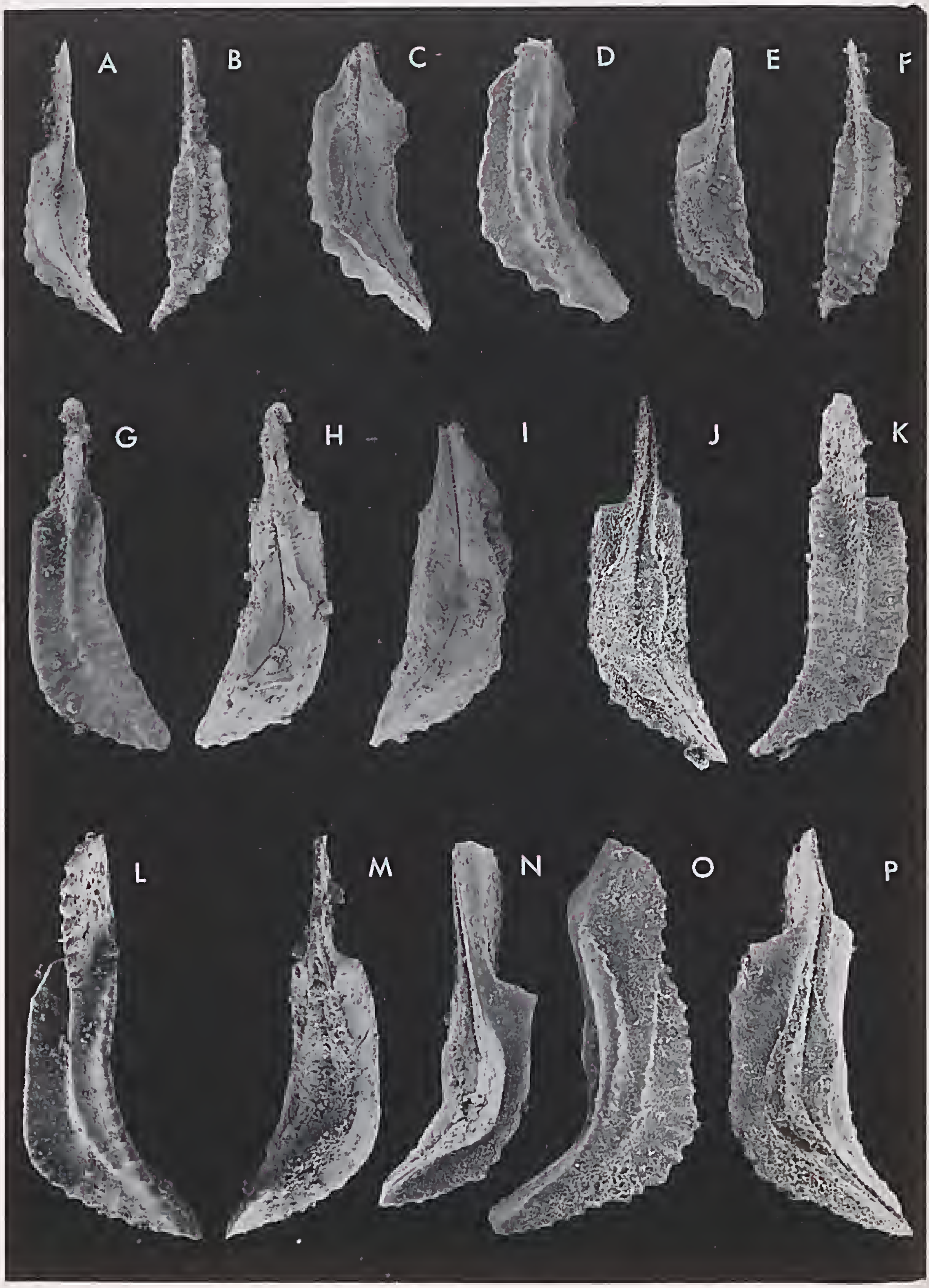
Contra Bischoff & Argent (1990), we feel there is no compelling evidence from which to infer an interval referrable to the *pesavis* Zone in the lower part of the Waratah Limestone at Walkerville and Grinder Point. We attach little significance to absences, in this instance of *Eognathodus sulcatus* morphs, especially as the earliest morphs transitional from *Ozarkodina pandora* are not present. There are thus, in our view, no grounds for considering the transgression represented by the basal Waratah Limestone to have predated the limestones of the Tyers–Boola area from which *E. sulcatus* was first described (Philip 1965). They may well have been coeval, as was postulated elsewhere (Talent 1965, 1967, 1989; Talent & Yolkin 1987).

6. *Tabberabbera*

The Wentworth Group includes at least 25 significant limestone lenses, though most carbonate developments are conspicuously lacking or poor in macro-fossils. In the hope of obtaining greater precision in alignment of the Wentworth Group with the conodont zonal scheme presently accepted for the Early Devonian, most carbonate horizons delineated in earlier mapping (Talent 1963) were sampled, most by 5–10 kg samples, some more copiously. Because the Tabberabbera area and the Tabberabberan Orogeny have such prominence in the geology of eastern Australia, the results of this investigation, though largely negative, are presented here.

Only three horizons proved fruitful: limestone boulders in the Wildhorse Formation at locality 97 (Scenic Lookout), and autochthonous limestone lenses in the Kilgower Member of the Tabberabbera Formation at localities 52 and 92 (Fig. 3A; Table 6). The largest limestone lens in the Kilgower Member, extending across the Rocks Creek–Pat Creek divide, was extensively sampled in the vicinity of locality 51 and where it outcrops in road cuttings on the new road from Cobbannah Creek to Angusvale; all samples proved to be barren of conodonts. Limestone cobbles in the Wild Horse Formation at locality 97 occur over a distance of c. 95 m along the road cutting, are exceptionally up to 50 cm in size, and are often coarsely crinoidal, dolomitic and pyritic. We know of no potential source for these limestones. As they were already lithified before incorporation into the Wild Horse Formation, an appreciable age-difference between them and the Wentworth Group is conceivable. We believe, however, that any age-difference is most likely trivial—much less than can be discriminated on the basis of presently known ranges of late Pragian conodonts.

We infer from our data from Boulder Flat, where *Polygnathus trilinearis* occurs in association with *P.* cf. *pireneae*, that the occurrence of *P. trilinearis* in limestone clasts in the Wild Horse Formation is best interpreted as evidence for an age not appreciably older than the *pireneae* interval. The other forms obtained, *Pand. steinhornensis steinhornensis, Pand. exigua philipi*, and *O. pseudomiae*, are consistent with this age assignment. A measure of caution should be exercised, however, as we do not have high quality data globally for the time-ranges of these forms and, moreover, we need more precise data regarding evolution of the earliest polygnathids *P. pireneae* and *P. trilinearis* in the late Pragian. The age indicated is thus very close to that previously advocated for the Wild Horse Formation and Kilgower Member (Talent 1963).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Limestone lenses in the Roaring Mag Member of the Tabberabbera Formation were sampled extensively at Whitbournes Point in Sandys Creek, on the Gorge Gully–Sandys Creek divide, and at Horseshoe Bend, Tabberabbera; all, surprisingly, proved barren. These limestones are thin, interbedded with siltstone, generally 1–3 cm in thickness, often stylolitic or intricately sheared, and are notable for rarity or lack of macrofossils. The limestone lenses and associated clastics in the vicinity of the Horseshoe Bend saddle contain deformed brachiopods tentatively assigned to *Spinella* and *Buchanathyris.* It was on the basis of these that the Roaring Mag Member was suggested to be broadly correlative with the Buchan Caves Limestone (Talent 1963). Silicified gastropods, worms (cf. *Spirorbis*) and occasional brachiopods (including *?Spinella and Buchanathyris*) were obtained from the prominent limestone outcropping immediately north of the junction of Sandys Creek with the Mitchell River (illustrated by Easton 1938). This unit proved to be barren of conodonts.

We can therefore add no new data that may help arrive at a more precise age for the Roaring Mag Member. However, conodont data presented here for the Wild Horse Formation and Kilgower Member suggest that the transgression represented by the basal units of the Wentworth Group probably aligns with the transgression represented by the Buchan Caves Limestone and not with the transgression represented, for instance, by the Waratah Limestone at Waratah Bay (Talent 1989). If this is accepted, the transgression inferred to have been connected with the deepening represented by the Roaring Mag Member may align with the deepening event expressed by the swift change from shallow shelf Buchan Caves Limestone to pelagic Taravale Formation at Buchan and the deepening within the upper Buchan Caves Limestone at Bindi, i.e. commencing late in the *dehiscens* Zone.

7. *Conclusions*

Despite low diversities, low yields and a high proportion of barren samples, conodont data indicate approximate contemporaneity of the Buchan Caves Limestone, the Cavan Formation, the limestone at Boulder Flat, the presumed olistostromal limestones at Loyola, the uppermost carbonate horizons of the "Coopers Creek Formation" at Tyers (Mawson et al., in prep.) and, seemingly, the lower part of the Wentworth Group and perhaps the Bell Point Limestone at Waratah Bay. All, with the exception of the last, have produced conodonts indicative of the latest Pragian *pireneae* Zone (or Subzone). The Pragian–Emsian boundary clearly lies within the Cavan Formation below the "Cavan Bluff Limestone" and within the Buchan Caves Limestone. High precision eludes us, however, regarding correlation of the lowest horizons of the Cavan Formation (due to absence of carbonates), the Buchan Caves Limestone (due to dolomites), and the limestone at Boulder Flat (bad outcrops and barrenness). All conceivably could extend from the *pireneae* interval down into the *kindlei* interval *sensu stricto* but, in the absence of any hint of this in the conodont data presently available to us, and in view of general considerations discussed below, we do not view this as probable.

It seems clear, nevertheless, that all of the above coeval or approximately coeval units, the Roaring Mag Member apart, reflect aspects of a transgressive event that was widespread in south-eastern Australia. It had been assumed earlier (Talent & Yolkin 1987; Talent 1989) on the basis of data then available that this event probably aligned with the base of the *dehiscens* Zone, the base of cycle Ib of Johnson et al. (1985). They had suggested a global transgression event near the base of the *dehiscens* Zone (in fact, just prior to it in Central Asia), an earlier transgressive event commencing at about the *sulcatus–kindlei* boundary, and an intervening major regressive phase aligning approximately with the *pireneae* interval. Unpublished data (Mawson & Talent 1992; Talent & Mawson, in prep.) from the Wellington–Mumbil–Stuart Town area of east-central New

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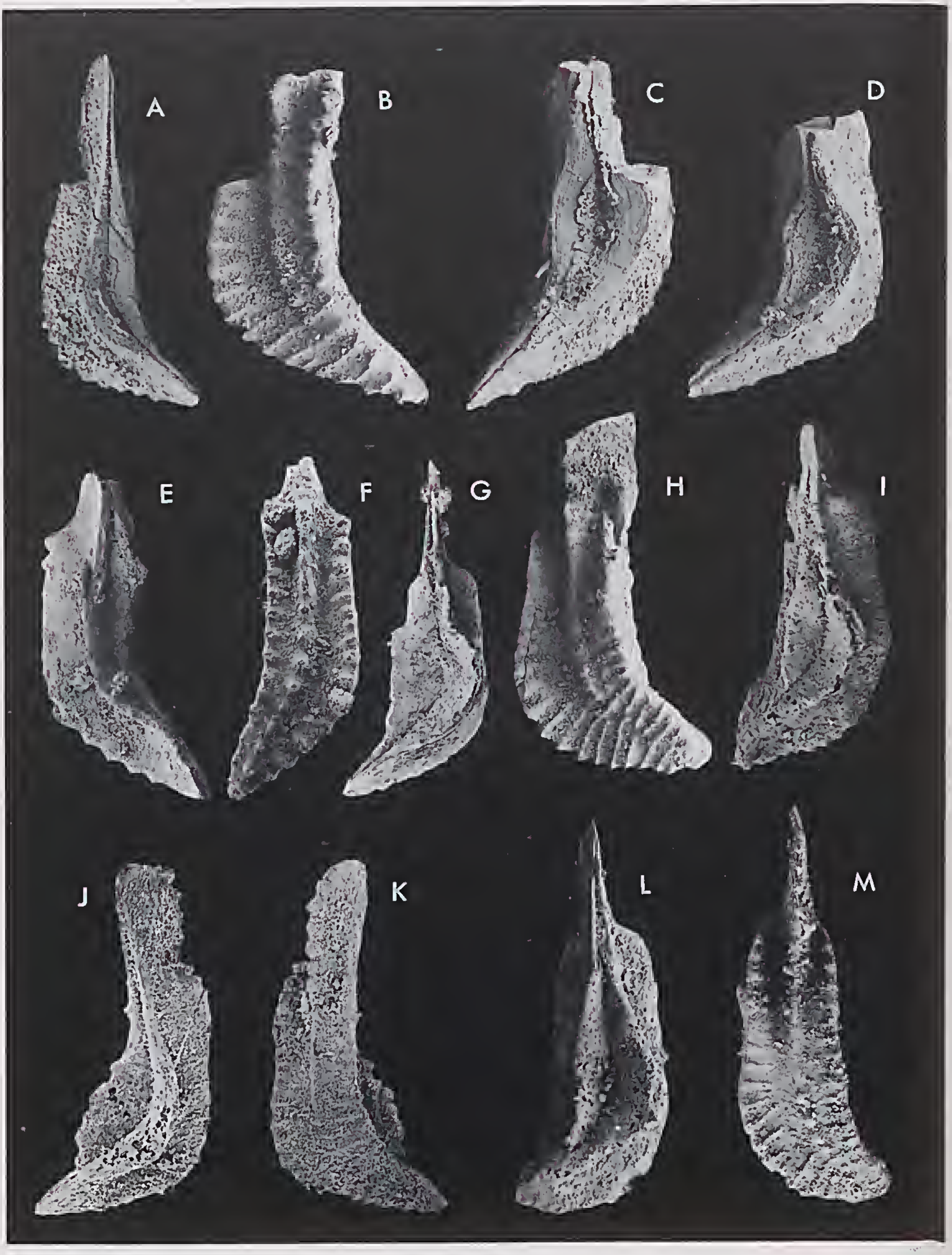
Fig. 7. A–F, *Polygnathus pireneae* Boersma. A, B, NMV P142080, Pa element lower and upper views, × 70, CABL67.6. C, NMV P142081, Pa element lower view, × 100, CABL71. D, NMV P142082, Pa element upper view, × 60, CABL73.4. E, F, NMV P142083, Pa element lower and upper views, × 50, CABL75. G, H, *Polygnathus pireneae–dehiscens* transitional form, NMV P142084, Pa element upper and lower views, × 45, CABL76. I–K, *Polygnathus dehiscens dehiscens* Philip & Jackson. I, NMV P142085, Pa element lower view, × 60, SR125. J, K, NMV P142086, Pa element lower and upper views, × 60, BON46–50. L–N, *Polygnathus dehiscens abyssus* Mawson. L, M, NMV P142087, Pa element upper and lower views, × 60, SR125. N, NMV P142088, Pa element lower view, × 60, SL80. O, P, *Polygnathus nothoperbonus* Mawson, NMV P142089, Pa element upper and lower views, × 60, BON46–50.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South Wales are in accord with a regressive event with platform exposure and development of submarine fans (Red Hill "Limestone") having occurred *within* and seemingly having been terminated by major transgression *before* the end of the *pireneae* interval. If the data from the Wellington–Mumbil–Stuart Town area and from south-eastern Australia reflect global eustatic events rather than local tectonic events, and if the transgressions and regressions in the two areas were coeval, the major transgressions represented by the Buchan Caves Limestone and Cavan Formation may have occurred within the *pireneae* interval, presumably very early in it, rather than aligning with the Johnson et al. (1985) transgression at about the *sulcatus–kindlei* boundary. Unfortunately, data presently to hand are not sufficient for an unequivocal answer to this question.

INFERRED CONODONT BIOFACIES

It has been pointed out elsewhere (Mawson et al. 1988; Mawson & Talent 1989) that, during Early Devonian times in eastern Australia, near-shore environments were populated principally by conodont animals bearing ozarkodinan elements or simple cones, whereas elsewhere icriodids were typical of this environment. Symptomatic of this virtual exclusion is that, despite much conodont work on the Lower Devonian of Victoria, only one icriodid has been reported to date, namely from the lower Pragian at Tyers (Philip 1965). It is not uncommon for Australian Early Devonian faunas to be dominated by ozarkodinans and simple cones to the virtual exclusion of all other forms; for example, in the SL section at The Basin (Table 3). For Australia, therefore, an Ozarkodinan Biofacies was substituted for the Icriodid Biofacies of the northern hemisphere. Clearly, for reasons unknown, such icriodid lineages as reached Australia during the Devonian were unable to proliferate, despite an abundance of near-shore environments that one might imagine to have been appropriate. These, admittedly, were subject to major transgressive and regressive (T/R) events destabilizing the environment (Talent & Yolkin 1987; Talent 1989), some of these events having been connected with regional orogenesis. But T/R events, even if not always as spectacular as those experienced in eastern Australia, occurred globally during the Early Devonian (Johnson et al. 1985).

In somewhat deeper, relatively quieter waters than those typical of the Ozarkodinan Biofacies, polygnathids and pandorinellinids were generally dominant, forming a Polygnathid Biofacies. Such, for example, is typical of the nodular limestones, shales and impure limestones of the Emsian (late *dehiscens* to *serotinus* zones) Taravale Formation at Buchan, Bindi and The Basin (Mawson 1987a; Mawson et al. 1988). The incoming of this biofacies coincides with the incoming of pelagic elements, specifically ammonoids and dacryoconarids, and significant change in the brachiopod and coral faunas (Talent 1985). Tabulate corals, stromatoporoids, algae and sponges virtually disappear. This event, within the *dehiscens* Zone, has been interpreted as an especially widespread, possibly global transgression (Talent & Yolkin 1987; Talent 1989). The change from Ozarkodinan to Polygnathid biofacies is apparent in the combined SR–BON section at Bindi and the CABL section at Wee Jasper.

The Basin

The SL section at The Basin (Fig. 2A, Table 3) is unequivocally representative of the Ozarkodinan Biofacies; all Pa elements of the fauna are ozarkodinans. The remarkably low diversity in brachiopods, restricted to *Spinella* and *Buchanathyris* to the virtual exclusion of all others, occasional tabulate corals, mainly species of *Favosites* and *Syringopora*, and of rugose corals, principally *Chalcidophyllum recessum* (Hill) and very rare *Acanthophyllum*, is consistent with very shallow water, possibly of abnormal salinity. An interval with high diversity in silicified

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Fig. 8. A, *Polygnathus dehiscens dehiscens–nothoperbonus* transitional form, NMV P142090, Pa element lower view, × 75, BON36–39. B–D, *Polygnathus nothoperbonus* Mawson. B, C, NMV P142091, Pa element upper and lower views, × 60, BON60.5–65. D, NMV P142092, Pa element lower view, × 60, BON60.5–65. E–K, *Polygnathus perbonus* (Philip). E, F, NMV P142093, Pa element lower and upper views, × 80, SR125. G, NMV P142094, Pa element lower view, × 45, SL60. H, I, NMV P142095, Pa element upper and lower views, × 45, BON56–60.5. J, K, NMV P142096, Pa element lower and upper views, × 60, BON46–50. L, M, *Polygnathus dehiscens abyssus–perbonus* transitional form, NMV P142097, Pa element lower and upper views, × 60, BON36–39.


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Phase	Metres above base of composite section	Ratio *Oz + S : Pa + Po*	Salient features of fauna	Inferred relative depth
1	0 - 61.9	34 : 1	No polygnathids	Very shallow
2	64.6 - 65.5	1 : 6	Brief incoming of polygnathids	Brief deepening event
3	66 - 108.8	15 : 1	Pandorinellinids persist but no polygnathids present	Shallow conditions, but not as shallow as in Phase 1
4	110.6 - 123.4	3 : 1	Prevalence of pandorinellinids	Deepening
5	123.9 - 234.8	1 : 1.17	Reappearance and persistence of polygnathids	Further deepening; marginal Polygnathid Biofacies

Table 7. Ratios of conodont genera, and inferred relative water depths of faunas from the combined SR–BON section at Bindi. Oz = ozarkodinans, S = simple cones, Pa = pandorinellinids, and Po = polygnathids.

molluscs, principally bivalves, occurs near the top of the section, but there is no increase in diversity of brachiopods and apparently no change in lithofacies.

Bindi

The two sections at Bindi, SR (Sawpit Ridge) and BON (Bonanza Gully), taken together, provide a continuous section through the Buchan Caves Limestone (BON 0 is the projection northwards along strike of SR256.5; Tables 2 and 3; Fig. 6). A succession of five conodont biofacies can be discriminated (Table 7). The first 61 m of section, Phase 1, is dominated by ozarkodinans; in Phase 2, between 66.6 and 65.5 m, there is a brief deepening event with incoming of a few polygnathids. During Phase 3 shallow conditions resumed but in Phase 4, commencing at 110.6 m above the base of the section, the fauna was enhanced by entry of relatively abundant pandorinellinids, otherwise typical of the Polygnathid Biofacies but not in sufficient numbers for the interval to be referred to that biofacies. During Phase 5, commencing 123.9 m above the base of the composite section, polygnathids appeared again and persisted, marginally outweighing ozarkodinans and simple cones. This last phase is therefore referred to as a marginal Polygnathid Biofacies.

In a paper on lower Middle Devonian conodonts from north-central Ohio, Sparling (1984) included species of *Panderodus* together with polygnathids when establishing biofacies units; he assigned other simple cones to shallower biofacies. If Sparling's lead were to be followed for the SR–BON section, both Phase 4 and Phase 5 would have an ozarkodinan + simple cone − *Panderodus versus* polygnathid + pandorinellinid + *Panderodus* ratios of close to 1:2. Both could therefore be referred to the Polygnathid Biofacies.

East Buchan

The MRD section at East Buchan yielded very poorly, doubtless because of excessively shallow water. Dolomite is more abundant in this

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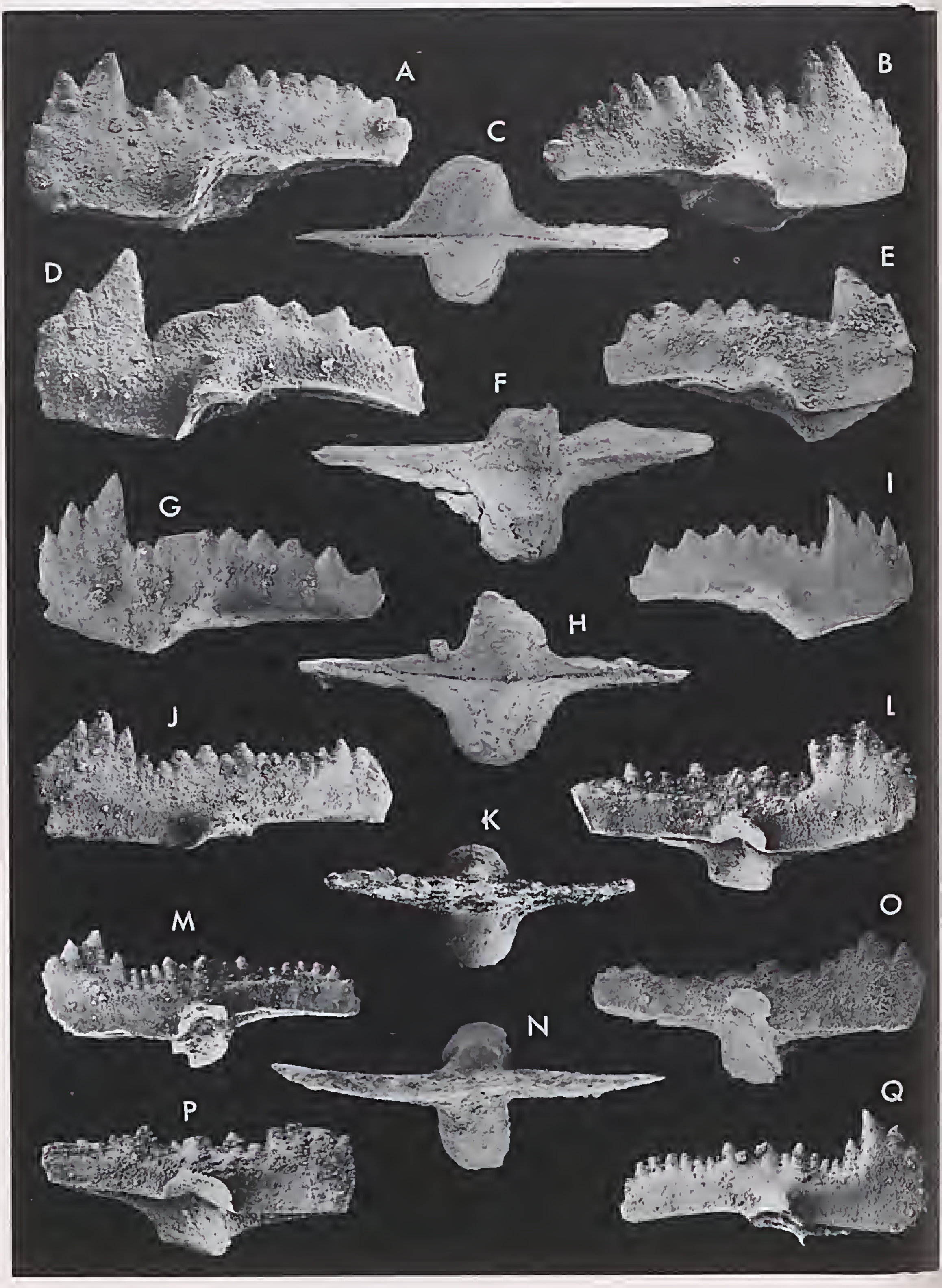
Fig. 9. A–G, *Polygnathus trilinearis* (Cooper). A, B, NMV P142098, Pa element upper and lower views, × 60, BF3. C, D, NMV P142099, Pa element upper and lower views, × 80, BF7. E, NMV P142100, Pa element upper view—note the centre row of denticles forming the blade, × 45, BF4. F, G, NMV P142101, Pa element upper and lower views, × 40, BF7. H, *Polygnathus* cf. *pireneae* Boersma, NMV P142102, Pa element upper view of broken specimen, × 70, BF4. I, J, *Ozarkodina buchanensis* (Philip). I, NMV P142103, Pa element lateral view, × 60, BF7. J, NMV P142104, Pa element lateral view, × 65, BF7. K, L, *Pandorinellina exigua philipi* (Klapper). K, NMV P142105, Pa element lateral view, × 60, BF7. L, NMV P142106, Pa element lateral view, × 60, BF7. M, *Amydrotaxis* sp., NMV P142107, Pb element lateral view, × 20, BF6. N, O, *Ozarkodina linearis* (Philip). N, NMV P142108, Sa element, × 60, DH49.6. O, NMV P142109, Sc element, × 50, DH49.6.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section than in other sections sampled and increases south-eastwards towards the Back Creek area of East Buchan where it is at a maximum for the Buchan Caves Limestone. No conodonts were recovered from 20 samples collected in the first 126 m of section, though approximately 100 kg from McColl's Dam, a few metres above the base of the Buchan Caves Limestone about a kilometre south of MRD, produced a small fauna. Only 7 of the next 51 samples on the MRD section yielded conodonts. From the little evidence available (Table 5), the MRD section is representative of the Ozarkodinan Biofacies with ozarkodinans outweighing polygnathids 20:1.

Boulder Flat

All productive spot samples from Boulder Flat have polygnathids and pandorinellinids and represent the Polygnathid Biofacies. The ratio of polygnathids plus pandorinellinids to ozarkodinans plus simple cones is 4:1.

SYSTEMATIC PALAEONTOLOGY

As most of the conodont fauna has been fully described in earlier papers (e.g. Philip 1966; Mawson 1987a), we have documented most of the species recovered by means of illustration. Description is limited to forms regarded as new or where comment is deemed necessary. Type and figured specimens are housed in the invertebrate palaeontological collections of the Museum of Victoria (NMV). Precise horizon and locality data for each sample number can be obtained by reference to Figs 1–3 and 5, and Tables 2–6.

Genus **Ozarkodina** Branson & Mehl, 1933

Type species. Ozarkodina typica Branson & Mehl, 1933.

Discussion. Knowledge of the Sa element is pivotal for differentiating *Ozarkodina* from *Pandorinellina*. In *Ozarkodina* the posterior process is expressed as a slight swelling on the posterior base of the cusp ("trichonodellan" form); in *Pandorinellina* this process is well developed ("diplodellan" form) (Klapper & Philip 1971; Klapper in Ziegler 1973). In our collections there is a dearth of Sa elements that can be assigned with certainty to either *Ozarkodina* or *Pandorinellina*. The new species proposed below is referred to *Ozarkodina* rather than to *Pandorinellina* because no diplodellan Sa elements are represented in the collections, and in view of the particular disposition of the anterior denticles along the blade.

Ozarkodina pseudomiae sp. nov.

Fig. 11A–Q

Ozarkodina buchanensis (Philip).—Mawson 1987a, pl. 37, fig. 11 [Pa element].

Etymology. pseudo (Gr. *pseudes* = false), in reference to the superficial similarity to *Ozarkodina miae* Bultynck.

Holotype. NMV P142128 (Fig. 11B) from Buchan Caves Limestone, 40.5m above the base of the SL section (sample SL28) at East Buchan.

Paratype. NMV P142127 (sample SL28) at East Buchan.

Additional material. One hundred and ten specimens from the CABL, SL, SR, and MRD sections, McColl's Dam and Loyola.

Diagnosis. Representative Pa elements of *O. pseudomiae* have a relatively broad, straight blade of medium length with numerous (average 11) small, stubby, triangular denticles. The symmetrical ear-shaped lobes of the basal cavity typically occupy the anterior part of the posterior half of the blade.

Discussion. O. pseudomiae and *Pandorinellina steinhornensis miae* (Bultynck) are easily differentiated on two grounds: the former has fewer,

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Fig. 10. A–I, *Pandorinellina exigua exigua* (Philip). A, NMV P142110, Pa element lateral view, × 60, SR247. B, NMV P142111, Pa element lateral view, × 60, SR247. C, NMV P142112, Pa element lower view, × 60, SR247. D, NMV P142113, Pa element lateral view, × 45, SR245. E, NMV P142114, Pa element lateral view, × 80, SR256.5. F, NMV P142115, Pa element lower view, × 60, SR256.5. G, NMV P142116, Pa element lateral view, × 60, BON21–23. H, NMV P142117, Pa element lower view, × 60, SR247. I, NMV P142118, Pa element lateral view, × 60, BON46–50. J–Q, *Ozarkodina prolata* Mawson. J, NMV P142119, Pa element lateral view, ×45, SR245. K, NMV P142120, Pa element upper view, × 80, SR257. L, NMV P142121, Pa element lateral view, × 45, SR245. M, NMV P142122, Pa element lateral view, × 45, SR245. N, NMV P142123, Pa element upper view, × 60, BON21–23. O, NMV P142124, Pa element lateral view, × 45, BON21–23. P, NMV P142125, Pa element lateral view, × 80, SR257. Q, NMV P142126, Pa element lateral view, × 45, SR245.

more even denticles, and the ear-shaped lobes of the basal cavity of *O. pseudomiae* are confined to the anterior half of the posterior portion of the blade. The lobes of the basal cavity of *Pand. s. miae* are heart-shaped and extend as a groove almost to the posterior of the blade. The denticles of *O. buchanensis* are much more irregular in size than those of *O. pseudomiae*, and the basal cavity is more centrally situated in *O. buchanensis.*

Ozarkodina linearis (Philip)

Fig. 12A–J

Discussion. Pathological conodont forms are frequently noted in collections but are rarely figured in publications. Three Sa elements of *O. linearis* are illustrated herein. One (Fig. 12H) is a normal specimen and two (Fig. 12I, J) are pathological forms. Weddige (1990) has suggested that such forms represent adverse conditions for the conodont animal, especially adverse feeding conditions. The distribution of forms exhibiting deformities may therefore cast some light on environmental pressures at the time. Weddige (1990: 568–572) has proposed a formal system for different types of "pathologies". If Weddige's scheme is followed, the two Sa elements of *O. linearis* in Figs 12I and 12J represent examples of duplicato pathology. Compared with a normal Sa element of the same species (Fig. 12H), these two specimens have a split or duplicate main denticle. It should be noted that most instances of duplication illustrated by Weddige (1990) are Early Devonian and occur predominantly in "spathognathodontan" apparatuses.

Genus Polygnathus Hinde, 1879

Type species. Polygnathus dubius Hinde, 1879.

Discussion. See Klapper (in Ziegler 1973) for discussion of the genus. During the past two decades there has been considerable discussion on the origin of polygnathids. Klapper & Philip (1972), Klapper & Johnson (1975) and Cooper (1973) favoured derivation from *Eognathodus*, whereas Lane & Ormiston (1979) and Sweet (1988) regarded *Ozarkodina* as the probable root stock for the polygnathids. The fauna from Boulder Flat adds strength to the argument for derivation from *Eognathodus.*

Polygnathus pireneae Boersma

Fig. 7A–F

Polygnathus lenzi Klapper.—Uyeno in McGregor & Uyeno 1972: pl. 5, figs 10–12 [Pa element].

Polygnathus n. sp.—Lane & Ormiston 1973: 330 [Pa element, not figured].

Polygnathus pireneae Boersma 1974: 287–288, pl. 2, figs 1–12 [Pa element].—Klapper in Ziegler 1977: 489–490, *Polygnathus* pl. 8, fig. 6 [Pa element].—Lane & Ormiston 1979: 62, pl. 3, figs 15–17, pl. 5, figs 2, 3, 9, 10, 27–34, 37 [Pa elements].—Klapper & Johnson 1980: 454 [Pa element].—Murphy & Matti 1982: 39–41, pl. 1, figs 33–38 [Pa elements].—Savage, Blodgett & Jaeger 1985: pl. 1, figs 21–26 [Pa elements].—Hou et al. 1988: 316–317, pl. 119, fig. 1 [Pa element].—Yolkin et al. 1989: 238, pl. 1, figs 1–6 [Pa elements].—Valenzuela Rios 1990: 62 [Pa element, not figured].

Polygnathus n. sp. R.—Al Rawi 1977: 57–58, pl. 5, fig. 47 [Pa element].

non *Polygnathus pireneae.*—Bischoff & Argent 1990: pl. 3, fig. 14 [Pa element].

Discussion. Murphy & Matti (1982) drew attention to the very small size of Boersma's specimens from the Spanish Central Pyrenees, noting the possibility for larger specimens to show development of adcarinal grooves. The smallest *P. pireneae* recovered from low in the CABL section is 0.7 mm in length (Fig. 7A, B) compared to only 0.42mm for the holotype (Boersma 1974, pl. 2, figs 1–3). Larger specimens from CABL, for example the specimen illustrated in Fig. 7E–F, measuring 0.9mm in length, show the development of adcarinal grooves on the anterior portion of the platform.

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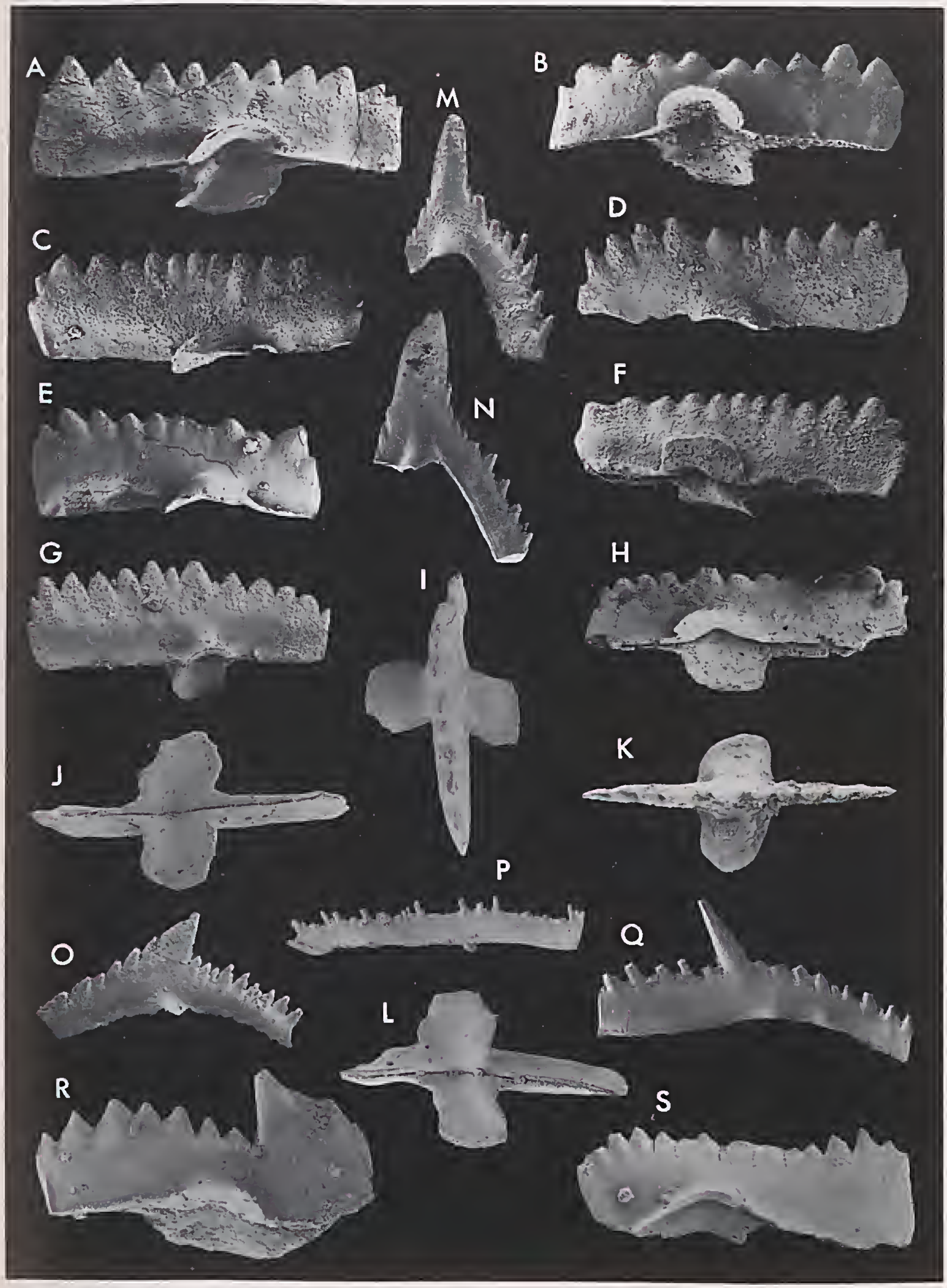
Fig. 11. A–Q, *Ozarkodina pseudomiae* n. sp. A, NMV P142127, Pa element lateral view, × 60, SL28. B, NMV P142128, Pa element lateral view of holotype, × 60, SL28. C, NMV P142129, Pa element lateral view, × 45, SL32. D, NMV P142130, Pa element lateral view, × 60, SL29.5. E, NMV P142131, Pa element lateral view, × 45, SL27. F, NMV P142132, Pa element lateral view, × 45, SL32. G, NMV P142133, Pa element lateral view, × 45, SL60. H, NMV P142134, Pa element lateral view, × 45, SL33. I, L, NMV P142135, Pa element upper and lower views, × 45, CABL79.7 J, NMV P142136, Pa element lower view, × 50, CABL78.5. K, NMV P142137, Pa element upper view, × 50, SL52. M, NMV P142138, M element lateral view, × 60, SL33.5. N, NMV P142139, M element lateral view, × 70, SL33. O, NMV P142140, Pb element lateral view, × 60, SL28. P, NMV P142141, Sc element lateral view, × 30, SL32. Q, NMV P142142, Sc element lateral view, × 60, SL33.5. R, *Pandorinellina exigua philipi* (Klapper), NMV P142143, Pa element lateral view, × 60, CABL67.6. S, *Ozarkodina selfi* Lane & Ormiston, NMV P142144, Pa element lateral view, × 60, CABL80.6.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The position of *P. boucoti* Savage, 1977 is somewhat enigmatic. Although Lane & Ormiston (1979: 62), Klapper (in Klapper & Johnson 1980: 454) and Bischoff & Argent (1990: 459) considered it to be a junior synonym of *P. pireneae*, it is not synonymised with that species here. If Savage's illustrations of *P. boucoti* are compared with those of the slightly smaller holotype of *P. pireneae* (0.5mm compared with 0.42mm), there are three salient differences: the proportion of blade to platform is much greater in *P. boucoti*, the platform is poorly developed in *P. boucoti* and, in lateral view, *P. boucoti* is high anteriorly, gradually decreasing in height posteriorly, whereas in *P. pireneae* the height of the unit is relatively uniform.

Yolkin et al. (1989) distinguished two forms of *P. pireneae*, A and B, both with large flaring basal cavities and Form B with a flattened upper surface. As both features are reminiscent of *P. trilinearis* (see below), it could be that *P. trilinearis* gave rise to what to date has been considered the earliest stock of the polygnathids, *P. pireneae*.

Polygnathus cf. pireneae Boersma

Fig. 9H

Discussion. Five polygnathids from Boulder Flat (Table 6) are compared with *P. pireneae*; none is complete. Although occurring in samples with *P. trilinearis*, these specimens are much narrower in proportion to their length. Compare, for example, *P. trilinearis* in Fig. 9C–D with *P.* cf. *pireneae* in Fig. 9H. Note that the specimens are of similar length. More complete specimens are required for unequivocal determination.

Polygnathus trilinearis (Cooper)

Fig. 9A–G

Spathognathodus trilinearis Cooper 1973: 79, pl. 3, figs 1, 6, 7 [Pa element].

Eognathodus trilinearis.—Klapper in Ziegler 1977: 123, *Eognathodus* pl. 1, fig. 4 [Pa element].

Discussion. Eleven polygnathids are referred to *P. trilinearis*, ten from Boulder Flat and one from locality 92 at Tabberabbera (Table 6).

In evolutionary lineages, novelty of a feature generally heralds the incoming of a new species or genus. Instance the first appearance of irregularity of denticles in the *Ozarkodina pandora–Eognathodus sulcatus* lineage (Murphy 1989) where a slight irregularity and non-alignment of the denticles is indicative of the incoming of *E. sulcatus eosulcatus* Murphy. In assigning *"S". trilinearis* to *Polygnathus*, the introduction of a third row of denticles on the oral surface is taken as the novel feature distinguishing an eognathodid from a polygnathid. According to Clark et al. (1981) and Sweet (1988), *Eognathodus* is characterised by having a double row of denticles, one row extending from the posterior to the anterior and forming the free blade anteriorly. A species diverging from this pattern by developing a third row of denticles and having a blade confluent with the central row of denticles should not be assigned to *Eognathodus.*

Cooper (1973) referred four well preserved specimens to *"Spathognathodus" trilinearis*, noting that the two principal differences between *"S". trilinearis* and the earliest polygnathids were: (a) the "continuity of the anterior blade with one of the outer rows of nodes on the platform"; and (b) the "prominent flaring lobes surrounding the basal cavity".

(a) Examination of the fifteen specimens from Boulder Flat and the one specimen from Tabberabbera has shown that the first difference between early polygnathids and *"S". trilinearis* is not always manifest. Though it is apparent that some specimens show continuity of the free blade with an outside row of nodes (e.g. Cooper 1973, pl. 3, fig. 6, and Fig. 9F herein), this is not always the case. In Fig. 9E (herein) it can be seen that the blade passes into the central row of nodes. This feature, therefore, appears to be an unstable feature and not one on which genera should be separated.

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Fig. 12. A–J, *Ozarkodina linearis* (Philip). A, B, NMV P142145, Pa element upper and lower views, × 45, SR129. C, NMV P142146, Pa element lateral view, × 35, SR129. D, NMV P142147, Pa element lateral view, × 45, SR190. E, NMV P142148, Pb element lateral view, × 60, CABL88. F, NMV P142149, Sc element lateral view, × 45, SR106.8. G, NMV P142150, Pb element lateral view, × 35, SR214.5. H, NMV P142151, Sa element lateral view, × 45, SR256.5. I, NMV P142152, Sa element, example of Duplicato Pathology *sensu* Weddige (1990), × 45, SR129. J, NMV P142153, Sa element, example of Duplicato Pathology *sensu* Weddige (1990), × 60, SR214.5. K–O, *Ozarkodina buchanensis* (Philip). K, NMV P142154, Pa element lateral view of juvenile specimen, × 100, CABL55. L, NMV P142155, Pa element lateral view, × 60, SL29.5. M, NMV P142156, Pa element lateral view, × 50, SR245. N, NMV P142157, Pa element lateral view, × 70, SR125. O, NMV P142158, Pa element lateral view, × 50, SL38.5.


A
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(b) By definition (Clark et al. 1981), the Pa elements of both *Eognathodus* and *Polygnathus* are carmiscaphate, i.e. having a capacious basal cavity; the "prominent flaring lobes surrounding the basal cavity" noted by Cooper (1973), therefore, pose no problem to placing *"S". trilinearis* in *Polygnathus*.

Lane & Ormiston (1979) suggested that Cooper's (1973) *"S". trilinearis* could be an aberrant form of *P. pireneae*. The former is now known from four localities: Loyola, Tabberabbera and Boulder Flat in Victoria, and associated with indubitable *P. pireneae* in a clast from the lower Cunningham Formation, 200 m stratigraphically beneath the Red Hill Limestone Member, 6.2 km north-north-west of Mumbil in allotment 65, parish of Mumbil, at grid reference 8732 I & IV Burrendong 90408325 in east-central New South Wales. Because of consistent morphology throughout the occurrences known to us we are convinced that *P. trilinearis* and *P. pireneae* are discrete species.

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REFERENCES

Al Rawi, D., 1977. Biostratigraphische Gliederung der Tentaculiten-Schichten des Frankenwaldes mit Conodonten und Tentaculiten (Unter-und Mittel-Devon; Bayern, Deutschland). *Senckenbergiana lethaea* 58: 25–79.

Andrews, E. C., 1938. The structural history of Australia during the Palaeozoic (The stabilization of a continent). *Journal of the Royal Society of New South Wales* 71: 118–187.

Argent, J. C., 1971. Stratigraphy and conodont biozonation of Lower Devonian limestones, Waratah Bay, Victoria. BA (Hons) thesis, Macquarie University.

Bischoff, G. C. O. & Argent, J. C., 1990. Lower Devonian (Late Lochkovian–Pragian) limestone stratigraphy at [*sic*!] conodont distribution, Waratah Bay, Victoria. *Courier Forschungsinstitut Senckenberg* 118: 441–471.

Boersma, K. T., 1974. Description of certain Lower Devonian platform conodonts of the Spanish central Pyrenees. *Leidse geologische Mededelingen* 49: 285–301.

Bradley, K., 1969. Geology of the Murrindal River–Yalmy River area east of Buchan, Victoria. *Proceedings of the Royal Society of Victoria* 82: 277–285.

Browne, I. A., 1959. Stratigraphy and structure of the Devonian rocks of the Taemas and Cavan area, Murrumbidgee River, south of Yass, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 92: 115–128.

Bultynck, P., 1989. Conodonts from the La Grange Limestone (Emsian), Armorican Massif, north-western France. *Courier Forschungsinstitut Senckenberg* 117: 173–203.

Clark, D. L., Sweet, W. C., Bergstrom, S. M., Klapper, G., Austin, R. A., Rhodes, F. H. T., Muller, K. G., Ziegler, W., Lindstrom, M., Miller, J. F. & Harris, A. G., 1981. *Treatise on Invertebrate Paleontology*, Part W, *Miscellanea*, Supplement 2, *Conodonta*. Geological

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Fig. 13. A, E, *Oulodus* sp. A. A, NMV P142159, Pa element, × 50, CABL72.5. E, NMV P142160, ?M element, × 60, CABL131.7. B–D, F, H, *Oulodus* sp. B. B, NMV P142161, Pa element, × 40, CABL71. C, NMV P142162, M element, × 20, CABL73.4. D, NMV P142163, Pb element, × 60, CABL84. F, NMV P142164, Sc element, × 50, CABL73.4. H, NMV P142165, ?Sb element, × 60, CABL131.7. G, *Oulodus* sp. C, NMV P142166, Pa element, × 50, TAB97. I, *Oulodus* sp. D, NMV P142167, Pa element, × 45, CABL129. J–L, *Ozarkodina* cf. *optima* (Moskalenko). J, NMV P142168, M element, × 60, TAB52. K, NMV P142169, Pb element, × 55, TAB97. L, NMV P142170, Pa element, × 60, TAB92. M, *Pandorinellina steinhornensis steinhornensis* (Ziegler), NMV P142171, Pa element, × 40, TAB97. N, *Neopanderodus aequabilis* Telford, NMV P142172, × 75, TAB52. O, *Pandorinellina exigua philipi* (Klapper), NMV P142173, Pa element, × 50, TAB97.

Society of America, Inc. and University of Kansas, Boulder, Colorado, and Lawrence, Kansas, 202 p.

Conaghan, P. J., Mountjoy, E. J., Edgecombe, D. R., Talent, J. A. & Owen, D. E., 1976. Nubrigyn algal reefs (Devonian), eastern Australia: allochthonous blocks and megabreccias. *Bulletin of the Geological Society of America* 87: 515–530.

Cooper, B. J., 1973. Lower Devonian conodonts from Loyola, Victoria. *Proceedings of the Royal Society of Victoria* 86: 77–84, pls 2, 3.

Cramsie, J. N., Pogson, D. J. & Baker, G. J., 1975. Yass 1:100,000 geological sheet. Geological Survey of New South Wales.

Cramsie, J. N., Pogson, D. J. & Baker, G. J., 1979. *Geology of the Yass 1:100,000 Sheet*. Geological Survey of New South Wales, 85 p.

Easton, J. G., 1938. The geology and physiography of the Mitchell River Gorge. *Mining and Geological Journal (Victoria)* 1 (3): 73–75.

Fletcher, K., 1963. The Snowy River Volcanics west of Buchan, Victoria. *Proceedings of the Royal Society of Victoria* 76: 169–179, pl. 20.

Hill, D., 1950. Middle Devonian corals from the Buchan district, Victoria. *Proceedings of the Royal Society of Victoria* 62: 137–164, pls 5–9.

Hill, D., 1954. Devonian corals from Waratah Bay, Victoria. *Proceedings of the Royal Society of Victoria* 66: 105–118, pls 6–9.

Hou Hong-fei et al. (eds), 1988. *Devonian Stratigraphy, Paleontology and Sedimentary Facies of Longmenshan, Sichuan.* Geological Publishing House, Beijing, 487 p., 184 pls.

Johnson, J. G., Klapper, G. & Sandberg, C. A., 1985. Devonian eustatic fluctuations in Euramerica. *Bulletin of the Geological Society of America* 96: 567–587.

Klapper, G., 1977. Lower and Middle Devonian conodont sequence in central Nevada; with contributions by D. B. Johnson. *University of California Riverside, Campus Museum Contributions* 4: 33–54.

Klapper, G, & Johnson, J. G., 1975. Sequence in conodont genus *Polygnathus* in Lower Devonian at Lone Mountain, Nevada. *Geologica et Palaeontologica* 9: 65–83.

Klapper, G. & Johnson, J. G., 1980. Endemism and dispersal of Devonian conodonts. *Journal of Paleontology* 54: 400–455.

Klapper, G. & Philip, G. M., 1971. Devonian conodont apparatuses and their vicarious skeletal elements. *Lethaia* 4: 429–452.

Klapper, G. & Philip, G. M., 1972. Familial classification of reconstructed Devonian conodont apparatuses. *Geologica et Palaeontologica* SB1: 97–113.

Krömmelbein, K., 1954. Devonische Ostrakoden aus der Gegend von Buchan und von der Küste der Waratah Bay. *Senckenbergiana lethaea* 35: 193–229, pls 1–5.

Lane, H. R. & Ormiston, A. E., 1973. Biostratigraphy of the Salmontrout Limestone, east-central Alaska. *Geological Society of America, Abstracts with Programs* 5: 30.

Lane, H. R. & Ormiston, A. E., 1979. Siluro-Devonian biostratigraphy of the Salmontrout River area, east-central Alaska. *Geologica et Palaeontologica* 13: 39–96, 12 pls.

McGregor, D. C. & Uyeno, T. T., 1972. Devonian spores and conodonts of Melville and Bathurst Islands, District of Franklin. *Geological Survey of Canada Paper* 71-13: 1–37.

Mawson, R., 1986. Early Devonian (Lochkovian) conodont faunas from Windellama, New South Wales. *Geologica et Palaeontologica* 20: 39–71

Mawson, R., 1987a. Early Devonian conodont faunas from Buchan and Bindi, Victoria, Australia. *Palaeontology* 30: 251–297.

Mawson, R., 1987b. Documentation of conodont assemblages across the Early Devonian–Middle Devonian boundary, Broken River Formation, North Queensland, Australia. *Courier Forschungsinstitut Senckenberg* 92: 251–273.

Mawson, R. & Talent, J. A., 1989. Late Emsian-Givetian stratigraphy and conodont biofacies—carbonate slope and offshore shoal to sheltered lagoon and nearshore carbonate ramp—Broken River, North Queensland, Australia. *Courier Forschungsinstitut Senckenberg* 117: 205–259.

Mawson, R. & Talent, J. A., 1992. Molong Platform and Hill End Trough (NSW) in the Early Devonian: a pattern of platform exposure and reciprocal carbonate sedimentation offshore. *Geological Society of Australia Abstracts* 32: 180.

Mawson, R., Talent, J. A., Bear, V. C., Benson, D. S., Brock, G. A., Farrell, J. R., Hyland, K. A., Pyemont, B. D., Sloan, T. R., Sorentino, L., Stewart, M. I., Trotter, J. A., Wilson, G. A. & Simpson, A. G., 1988. Conodont data in relation to resolution of stage and zonal boundaries for the Devonian of Australia. *Memoir of the Canadian Society of Petroleum Geologists* 14: 485–527.

Mawson, R., Talent, J. A. & Jell, J. S., 1985. Stage boundaries within the Devonian: implicaitons for application to Australian sequences. *Courier Forschungsinstitut Senckenberg* 92: 251–273.

Mawson, R., Talent, J. A., et al., in prep. Age of Early Devonian submarine fan deposits and isolated limestone megaclasts, east-central Victoria.

Murphy, M. A., 1989. Lower Pragian boundary (Lower Devonian) and its application in Nevada. *Courier Forschungsinstitut Senckenberg* 117: 61–70.

Murphy, M. A. & Matti, J. C., 1982. Lower Devonian conodonts (*hesperius–kindlei* Zones),